REPORT AND ACCOUNTS OF

The Scottish Association for Marine Science

for the period 1 April 1999 to 31 March 2000

The Dunstaffnage Marine Laboratory, Firth of Lorn, with the Laboratory's larger research vessel *Calanus* at the pontoon (right). *© John Anderson, Highland Image*

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Director's Introduction

Professor Graham Shimmield

Last year I wrote about "coping with change", little realising the impending decision of the NERC Council to dissolve the Centre for Coastal and Marine Sciences (CCMS) and the effects this would have on marine science strategy in the UK. Although this decision was taken at the end of June 2000, major changes within CCMS occurred at the beginning of the year when Professor Jacquie McGlade stepped down from the Directorship and I was asked to take on the role of Acting Director. Over the following six months, staff at the Laboratory, and at our sister sites, engaged in major operational and financial re-organisation, producing a detailed manifesto for the future of CCMS, which was abruptly terminated.

What is the relevance of this to SAMS and why lead with this in an Introduction to the Annual Report 1999–2000? The reason is that this decision, and the consequent potential ratification by NERC of SAMS as the single organisation with the responsibility for operation and management of the Dunstaffnage site, marks an historic return to the unification of scientific activity at Dunstaffnage. Over the coming months our scientific programme, and how it will be funded, will be clarified and I look forward to the end of a somewhat schizophrenic period in our history. However, in the year recorded in these pages, I present to you accounts of the achievements of both SAMS and DML science, commending the quality and dedication of all the scientists, support staff and administration at Dunstaffnage.

In this year the ability of SAMS to underpin basic and fundamental marine science in Scotland has been further endorsed. A successful bid to the Joint Infrastructure Fund, led by Professor Monty Priede of the University of Aberdeen, and with support from colleagues at the Universities of St Andrews and Bristol, has led to almost £1 million being invested in siting seabed

Director's Introduction

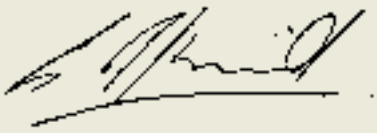
"landers" and associated infrastructure at Dunstaffnage. Construction work also commenced on the new Data Warehouse facility for the University of the Highlands and Islands project (UHIp), which will place Dunstaffnage at the forefront of digital computational and communication development in the Highlands and Islands. Through major support from Highlands and Islands Enterprise, and in conjunction with Heriot-Watt University (Professor Brian Austin), the first steps in the field of marine biotechnology have been taken with the creation of a new company, the European Centre for Marine Biotechnology. Work is currently underway to consolidate this development with an application for funds for a new facility at Dunstaffnage.

SAMS science continues to grow in volume and stature. I particularly draw attention to the excellent progress in zooplankton dynamics led by Dr Geraint Tarling, following Professor Jack Matthews' seminal work, and Dr Maeve Kelly in developing a considerable research portfolio in invertebrate biology and mariculture. Deep-sea corals have seldom been out of the press, finding themselves cited under the European Habitats Directive in a court case between Greenpeace and the Government. Professor John Gage's research group continues to lead the UK's fundamental research effort into these fascinating organisms. Dr John Gordon has raised both scientific and political interest in the fate of deep-water fish stocks to the west of Scotland, with an exemplary portfolio of scientific and industry publications. Dr Ray Leakey continues to expand marine microbial ecology research at SAMS whilst engaging in technology transfer with colleagues at the University of Karachi, Pakistan. Marine biogenic trace gas research has consolidated with the well-earned extension to Dr Angela Hatton's NERC Fellowship. In geochemistry, Dr Tracy Shimmield has established the inductively coupled mass spectrometer (ICP-MS) facility for fish ear bone microchemistry and palaeogeochemistry, winning a variety of EU grants. The UHIp lecturers, Drs Keith Davidson, Mark Inall, John Howe and Axel Miller, have emphasised their capability in winning research grants and preparing for the launch of the BSc in Marine Sciences with the UHIp in September 2000.

The relationship between DML and SAMS staff at the Laboratory is stronger than ever. A key new appointment of Dr Chris Bolch as Head of the Culture Collection for Algae and Protozoa (marine) has provided excellent collaborative opportunities which have been capitalised on by SAMS staff.

In July last year, Dr Alan Ansell passed away. Alan's work was a cornerstone for the reputation of the SMBA and SAMS over the forty years that he worked both at Millport and Dunstaffnage. We miss his enthusiasm, warmth and humour greatly.

In the months to come, clarity and purpose in our scientific and educational roles will be paramount. Optimism, tinged with anxiety, is the mood as we complete this account of our scientific activity over the reporting year. Bringing our marine science to the attention of both the public and politicians has never been more important. I pay tribute to the hard work and enthusiasm that Robin Harvey and Helen Anderson have put into this Annual Report and other activities. The work reported here is crucial for the future of Scotland as a maritime nation. I commend it to you.



Graham B Shimmield, FIBiol, FRSE
Director SAMS and DML

Geochemistry

Dr Tracy Shimmield

The Geochemistry Group has continued to carry out research into the effects of human impacts on the marine environment.

The research undertaken is diverse and includes radionuclide and heavy metal geochemistry. The main aims of the group are to use geochemistry to trace marine processes such as diagenesis, identify and utilise proxy indicators for use in palaeoceanographic research and to measure the rates of biogeochemical and physical processes such as sediment accumulation.

This work is underpinned by analytical facilities which include an Inductively Coupled Plasma Mass Spectrometer (ICP-MS) and alpha and gamma spectrometry equipment. In addition to these laboratory-based facilities, considerable progress has been made in the development and utilisation of lander-based *in situ* measuring devices. The following sections describe the results of some of these activities.

Laboratory, field and *in situ* study of metal behaviour and oxygen flux within a North Sea drill cuttings pile

Over the past three years, as part of the NERC Thematic Programme MIME (Managing Impacts in the Marine Environment), we have been conducting the simultaneous analysis of geochemical carrier substances (Mn and Fe oxyhydroxides), ^{210}Pb (to assess sediment mixing) and an indicator of drill cuttings (Ba) to identify the major processes controlling metal behaviour within North Sea oil and gas drill cuttings piles. This has been accomplished through the use of standard sediment sampling (Fig. 1), remotely operated vehicle technology and new microelectrodes capable of resolving rapid biogeochemical changes close to the sediment-water interface. Through this study we have observed that the most rapid biogeochemical reactions and fluxes take place near the centre of the cuttings pile. The largest total metal concentrations occur here (Fig. 2), in conjunction with a rapid rate of organic matter decomposition and oxygen consumption (Fig. 3). The precipitation of metal mono- and disulphides was directly observed within the pile. Radionuclide (^{210}Pb) depth profiles indicate that there was no sediment mixing at the station closest to the platform but mixing in the surface sediment is greater with increasing distance from the platform.

GB Shimmield (SAMS/DML) and
E Breuer (DML)

Fig. 1 Denise Cummings and Eric Breuer processing a sediment core taken close to the Beryl Alpha platform.

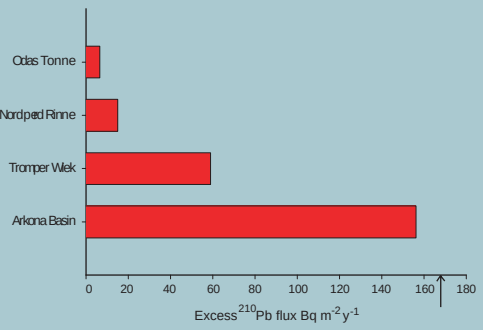


Fig. 4 Excess ^{210}Pb fluxes for all four stations studied. Arrow indicates calculated mean of global flux.

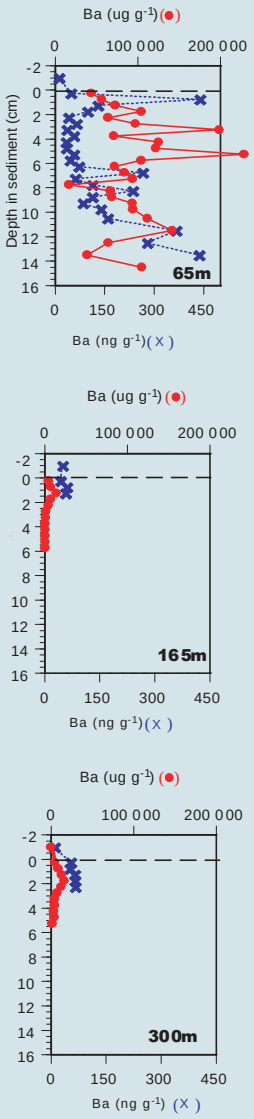


Fig. 2 Interstitial dissolved (x) and solid phase (●) barium concentrations measured in the sediments at three distances from an oil production platform. Barium contamination declines markedly with increasing distance from the drilling site. The dashed line represents the sediment-water interface.

Baltic Sea System Study (BASYS)

This three-year European Commission-funded programme, which ended in August 1999, resulted in a comprehensive study of a reduced salinity basin with restricted exchange and extensive pollutant inputs from surrounding catchment areas. The main contribution from SAMS was the study of natural and man-made radionuclides and stable lead isotopes. By studying sediment and nepheloid layer samples from four time-series observation stations it was hoped to discover how inputs from the River Oder were distributed within the Southern Baltic with respect to material fluxes and benthic processes. The study areas ranged from a site within the shallow water, high-energy area, Odas Tonne, to an area in the Arkona Basin where sediment was accumulating.

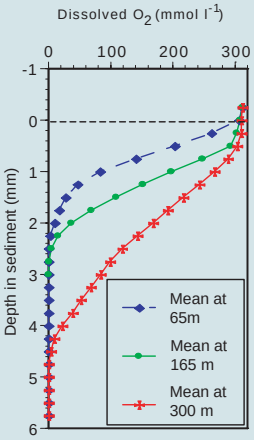


Fig. 3 Interstitial dissolved oxygen profiles from the Beryl "A" cuttings pile showing an increase in oxygen penetration with distance from the platform. The dashed line at 0-mm depth marks the position of the sediment-water interface.

^{210}Pb, a natural radionuclide, is introduced to the marine environment from the atmosphere. A small amount of ^{210}Pb is also produced *in situ* from ^{226}Ra in the water and sediment. The mean global flux of ^{210}Pb onto the landmass of the earth has been calculated as 166.5 Bq m^{-2} y^{-1}. The ^{210}Pb flux at each of the four time series stations can be compared (Fig. 4) to determine if there is an excess or deficiency of ^{210}Pb. A deficiency suggests a removal of sediment from an area and conversely an excess flux could indicate an addition of sediment. The calculated flux of 156.3 Bq m^{-2} y^{-1} obtained for the Arkona basin is within the expected error from atmospheric input. However the excess ^{210}Pb fluxes from the other three stations are considerably lower, ranging from 35% of the expected atmospheric flux for Tromper Wiek down to 4% for Odas Tonne .

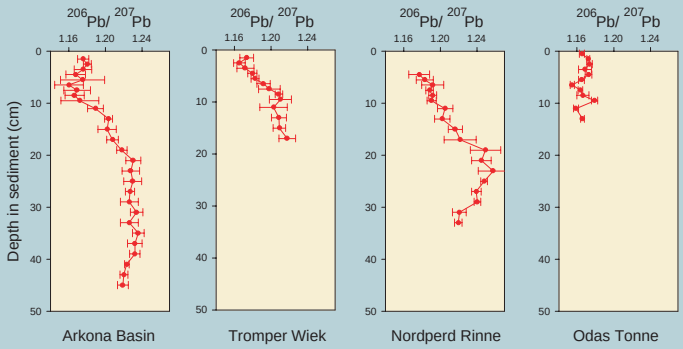


Fig. 5 Lead isotope profiles for Baltic Sea sediment cores.

These data suggest that fine nepheloid material from the high-energy stations closer to the Oder input is being removed and deposited in deeper water.

The source of lead (Pb) to the environment can be determined by studying stable Pb isotopes. Europe introduced alkyl Pb to petrol in 1922 and the $^{206}Pb/^{207}Pb$ isotope ratio in petrol is well-known and different from industrial and natural isotope ratios. Figure 5 illustrates the $^{206}Pb/^{207}Pb$ ratio for all four stations. The decrease in isotope ratio from deep in the core to the surface indicates the increasing amount of pollutant Pb derived from petrol. Three of the stations show this decrease in ratio towards the surface with the exception of Odas Tonne, the station closest to the Oder input. The ^{210}Pb flux data and the Pb isotope ratio profiles suggest that most of the material depositing in the Arkona basin is derived from nepheloid material transported there from shallower water, rather than from a direct surface input.

TM Shimmield (SAMS) and **GB Shimmield** (SAMS/DML)

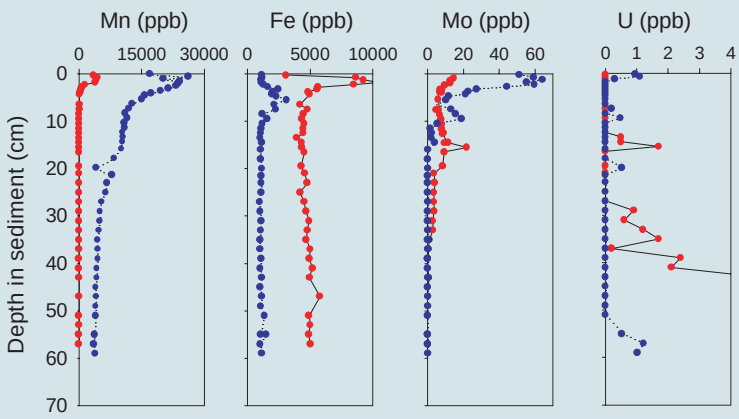
Restricted Exchange Environments

The Restricted Exchange Environments (REEs) programme is one of the six core programmes of the Centre for Coastal and Marine Sciences (CCMS). At a local scale, REEs occur where coastal topography controls the exchange of water masses between the shelf and inshore areas e.g. in sea lochs, fjords and estuaries. At a regional level, there are larger enclosed seas such as the Baltic and the Mediterranean which have a European importance. REEs are important to the economic and social welfare of the regions surrounding them and it is vital that the behaviour of such systems is understood to enable the effects of human intervention to be predicted.

At present, SAMS input to REEs is concentrated on the study of radionuclides and heavy metals within Loch Etive, a sea loch situated close to the Laboratory. This involves the collection and analysis of sediments, pore water and suspended particulates to assess the sediment accumulation and mixing rates and to determine the flux and inventories of heavy metals and radionuclides within the sea loch. Long term time-series data are being collected in the fields of physical oceanography, benthic biology and biogeochemistry, which will ultimately be used to construct a model describing sea loch behaviour. Figure 6 shows the differences in concentrations of redox-sensitive metals between two stations of differing water depth. This indicates that the amount of degradation of organic material and the depth of the redox boundary is different at these sites.

TM Shimmield and **T Sawyer** (SAMS), **GB Shimmield** (SAMS/DML), **J Foster,** and **E Breuer** (CCMS-DML)

Fig. 6 Porewater profiles from two stations of differing water depth in Loch Etive. ---•--- 40 m, ——— 145 m.



Deep-Sea Benthic Dynamics

Professor John Gage

Past research undertaken by SAMS at the continental margin off western Scotland has helped to underpin new commissioned work focused on assessing possible impacts from on-going oil and gas industry activities in what is now called the 'Atlantic Frontier'. These studies enhance our capability to respond to the challenge of providing impartial and high quality environmental assessment, while adding substantially to basic knowledge of the deep-sea environment in these still little-explored waters. Within this theme, topics reported on this year include studies on the deep-water coral *Lophelia pertusa*, and further analyses of macrofaunal data from the continental slope to the west of the Hebrides. Core science is represented by our participation in the NERC BENBO (Benthic Boundary Layer) Thematic Programme.

Benthic community activity and biomass in biogeochemical processes at the deep-ocean bed – NERC BENBO Thematic Programme

The BENBO Programme aims to compare biogeochemical processes in the deep-ocean benthic boundary layer at three contrasting sites in the north-eastern Atlantic. At SAMS we are examining the role of the benthic metazoan community in organic carbon turnover at the deep ocean floor by (i) estimating respiratory carbon demand and its partitioning among the different trophic groups and biomass size classes within each community and (ii) determining the role of the benthic fauna in biogenic particle mixing and transport (bioturbation) in organic matter recycling at the three sites.

The large box core samples collected during 1998 on the two BENBO research cruises have now been processed. Benthic megafauna collected using the Southampton Oceanography Centre epibenthic sled has been sorted and identified and biomass measurements made on representative specimens. Megafaunal densities have been quantified from sea-floor photographs taken during the sled tows, with the recovered specimens greatly aiding accurate identification of the visible fauna. Macro-infauna have now been extracted from four box cores per site, sorted and identified to major taxon or to family level, and biomass measurements of this material are now nearing completion. Meiofauna samples from the three study sites have also been analysed to complete the coverage of the benthic metazoan size spectrum (Fig. 7).

Our understanding of the role of bioturbation at the study sites has been advanced using samples of burrow contents collected by SAMS, which have been made available to BENBO co-workers for radionuclide and organic analysis. The results will allow a more accurate assessment of the effects of specific biogenic features on the structure of the sediment column at each site.

DJ Hughes and JD Gage (SAMS)

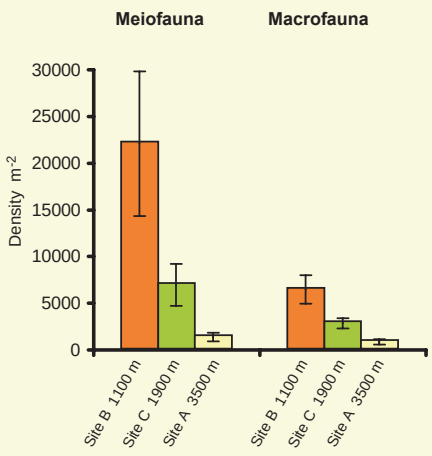


Fig. 7 Densities of infaunal benthic metazoans (>0.25 mm in size) at the three BENBO study sites. Data are presented separately for meiofaunal (nematodes, ostracods, harpacticoid copepods) and macrofaunal taxa (chiefly polychaetes, bivalves and peracarid crustaceans). Bars represent means of four box cores per site, ± 1 S.D. A steep decline in numbers with increasing depth is apparent for both faunal categories.

Deep-Sea Benthic Dynamics

Fig. 8 The Beryl Alpha platform in the North Sea and a colony of *Lophelia pertusa* that has colonised the flare support tower shown to the left of the main platform. The coral colony is about 30 cm across and was photographed from a remotely operated vehicle at a depth of 72 m. It is surrounded by orange sea anemones and dead man's fingers *Alcyonium digitatum*. Photos: J Murray Roberts, SAMS and SubSea Offshore Ltd., (courtesy of Anne Walls, Mobil North Sea Ltd.)

The sensitivities of cold water corals and other large megafauna to oil, gas and fishing activity at the Atlantic Frontier, west of Shetland.

This is one of five projects within MIME (Managing Impacts in the Marine Environment), a joint Government/oil industry-funded programme with the objective of providing scientific guidance to help manage the environmental impact of offshore oil and gas industry activities. The *Lophelia* study involves partners at five UK research centres. One aim is to improve our understanding of the distribution of coral and other large seabed organisms at the Atlantic Frontier. The high public profile of *Lophelia pertusa* required greater focus on corals and, together with colleagues at the British Geological Survey (BGS), we have produced a report and comprehensive map showing where *L. pertusa* has been found. Recent discoveries of the coral growing on oil production platforms in the northern North Sea (Fig. 8) have led to further examination of video survey records, with the aid of additional funding from Mobil North Sea Ltd. and the UK Offshore Operators Association.

Collaboration with the Norwegian Institute of Marine Research at Bergen allowed participation in a deep-water coral cruise in May, during which a new *in situ* optical recorder developed at Strathclyde University was deployed. DNA sequencing studies on the coral genotype undertaken at Southampton Oceanography Centre suggest that *L. pertusa*, although highly variable in growth-form and colour, is indeed a single species in the NE Atlantic, but there is evidence of genetic variability from site to site. There is also evidence of greater gene flow between some of the areas sampled, such as between Rockall and the Sula Ridge off Norway.

Skeletal analysis of carbon and oxygen isotopes has been carried out by BGS. These results have been integrated with trace element signals from high-resolution sampling of the coral skeleton using laser ablation combined with ICP-MS (inductively coupled plasma mass spectrometry). *Lophelia* samples from seven sites ranging from Spain to Norway have been investigated. Stable isotope chemistry showed that individual samples contained a significant portion of the total isotopic range detected across all samples, suggesting that controls on isotope incorporation were not radically different over the wide geographic range of the samples. Elemental chemistry has shown values not dissimilar to tropical corals, but although most data were at or close to detection limits, outliers for some metals suggest short-term increases in metal concentrations. Expansion of this work, to include coral samples recovered from the Beryl Alpha field in the North Sea, is planned.

JM Roberts and JD Gage (SAMS), **SR Chenery, B Spiro and D Long** (British Geological Survey), **AD Rogers** (Southampton Oceanography Centre), **A Cunningham** (University of Strathclyde) **and JB Wilson** (Royal Holloway University of London)

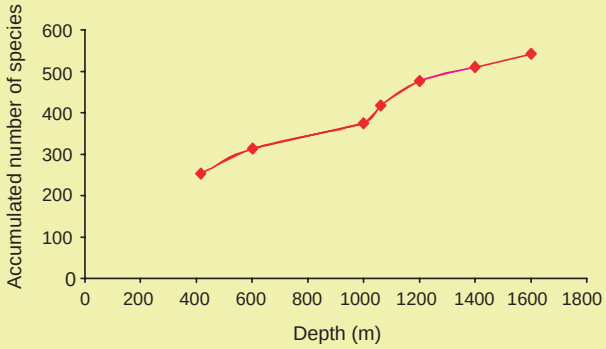


Fig. 9 Accumulation of previously unrecorded macrobenthic species in box cores on the Hebridean slope. The samples are assembled along the depth gradient and show a sharp, step-like increase in rate of accumulation at about 1000-1200 m, indicating a marked change in community composition at about this depth.

The macrobenthic community on the Hebridean margin

The allocation of further oil and gas exploration tranches to the west of Scotland has created a need for new environmental data from this area. Tranches 19–22 lie to the west of Barra, an area sampled intensively by SAMS since the 1970s. Thus, little new sampling was required there during the wide area survey carried out by the Southampton Oceanography Centre for the Atlantic Margin Environmental Network (AFEN) in 1998. The value of the existing SAMS dataset was recognised by an award of additional funds to SAMS from AFEN, a consortium of 21 oil/gas companies and the Government Regulator, to allow further analysis and presentation of box core sample data.

The existing data on the sediment environment and benthic biology have been reviewed and integrated with results from the NERC-funded Shelf Edge Study. The work on benthic macrofauna clarified the strong depth-related patterns in community composition and abundance. There is also a clear pattern in declining benthic biomass with increasing depth, but the results also show reduced biomass and species diversity just below the shelf edge where an active hydrodynamic regime prevails. No mid-slope peak in diversity, such as that described for the NW Atlantic, was detected. There is a striking change in macrofaunal composition between 1000 and 1200 m depth (Fig. 9), which corresponds to a peak in the rate of change of megafauna detected from analysis of trawl samples taken in the 1980s.

The deep-sea fauna is still not well described and different research groups may generate divergent species data. In order to normalise the accumulated data, a taxonomic comparison between the SAMS data and that generated from the AFEN survey samples was undertaken with the environmental consultants Cordah Ltd., to produce a harmonised species listing. Further need for data normalisation has also proved necessary as a result of differing sieve and sample size, and these results will be incorporated in reports to be published by AFEN in 2000 as a CD ROM set.

Miss Bhavani Narayanaswamy, a PhD student registered at Southampton University and sponsored by AFEN, has been studying the benthic biology along a depth-related transect in the Faeroe-Shetland Channel sampled in 1996 and in 1998). The unique water mass structure of this area provides a convenient setting for testing ideas on environmental controls on deep-sea macrobenthic abundance, biomass and species richness. Surprisingly, values for all of these parameters peak at 400-600 m depth where bottom water temperatures may change by up to 9°C in the space of one hour!

JD Gage and PA Lamont (SAMS) and **B Narayanaswamy** (University of Southampton)

© John Anderson, Highland Image

Bhavani Narayanaswamy processing a benthic sample.

Deep-Water Fish

Dr John Gordon

The final report of the SAMS co-ordinated EC FAIR shared-cost multi-national project *Developing deep-water fisheries: data for their assessment and for understanding their interaction with and impact on a fragile environment* was accepted by the European Commission. Its importance was recognised at an "open hearing on deep-water fishing" hosted by the EC in June 1999.

Dr Gordon represented the International Council for the Exploration of the Sea (ICES) and presented a report on the status of the deep-water fisheries in the ICES area. In February 2000, Dr Gordon completed his five-year term of office as chairman of the ICES Study Group on the Biology and Assessment of Deep-sea Resources. The results of the international collaboration in the FAIR project made a significant contribution to the Study Group's report.

In 1999, repeat trawls were conducted from RRS *Challenger* at a 1000 m station to the west of Barra, an area that was extensively sampled in the mid 1980s. This area is now heavily fished and the 1980s hauls represent the state of the fish populations before exploitation. The preliminary results from the new trawls were an important contribution to Joint Nature Conservation Committee-funded work on the effects of fishing on deep-water fish to the west of Britain and the full results are being prepared for publication.

Otolith microchemistry as a means of identifying stocks of deep-water demersal fish

This three-year EC shared-cost FAIR project (OTOMIC), co-ordinated by SAMS, began in January 1999. Its main aim is to use Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to quantify the levels of trace elements present in some deep-water fish otoliths (ear bones) and assess their usefulness for stock discrimination. Four deep-water species have been selected for this study: *Helicolenus dactylopterus* (bluemouth), *Merluccius merluccius* (hake) and *Nezumia aequalis* (smooth grenadier), found in both the eastern North Atlantic and Mediterranean, and *Coryphaenoides rupestris* (roundnose grenadier),

© Helen Anderson

Fig. 10 Pamela McGarr conducting microwave preparation of otoliths prior to ICP-MS analysis.

Fig. 11 Barium concentrations across a fish otolith as determined by laser ablation. The graph shows changes along the laser-etched transect indicated on the left.

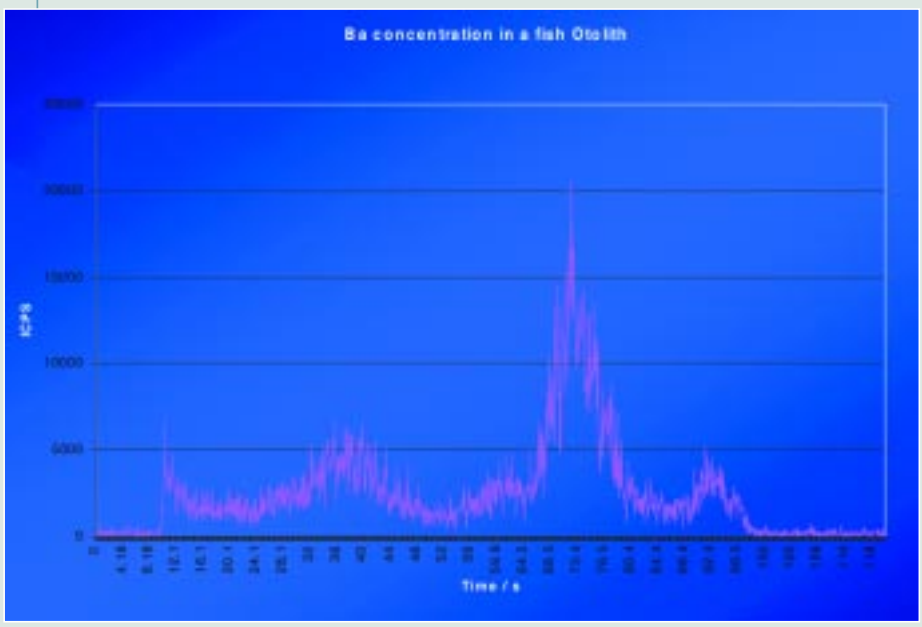
widely distributed throughout the North Atlantic. As they show varied life-history characteristics and occupy a wide range of habitats from the Atlantic to the Mediterranean, it is hoped that some of the processes influencing element incorporation might be elucidated.

Initial results indicate that all four of the study species have trace elements present at lower concentrations than many shallow-water species. Potentially useful elements for stock discrimination include strontium, iron, magnesium, aluminium, nickel, barium, chromium, manganese, cobalt, zinc and copper. Solution-based ICP-MS (Fig. 10) will also be used to analyse the central core of otoliths to try to establish where the fish may have been spawned. Complementary to this, laser-ablation ICP-MS (Fig. 11) will determine differences in the elemental composition of the otolith from the core to the outer edge, in order to ascertain whether the individual has migrated through different water masses.

JDM Gordon, GB Shimmield, S Swan and P McGarr (SAMS)

Distribution and biology of anglerfish and megrim in waters to the west of Scotland

This two-year, shared-cost EC Study Contract, co-ordinated by SAMS, is being carried out by Fisheries Research Services (Marine Laboratory, Aberdeen), the Marine Institute (Ireland) and SAMS. The overall aim is to investigate the growth, abundance and spawning behaviour of anglerfish *Lophius* spp. and megrim *Lepidorhombus* spp. in waters to the west of Scotland. In recent years, directed fisheries for both species have developed rapidly, resulting in heavy exploitation of the stocks, the current status of which is uncertain because of a lack of understanding of the biology of the species.



Deep-Water Fish

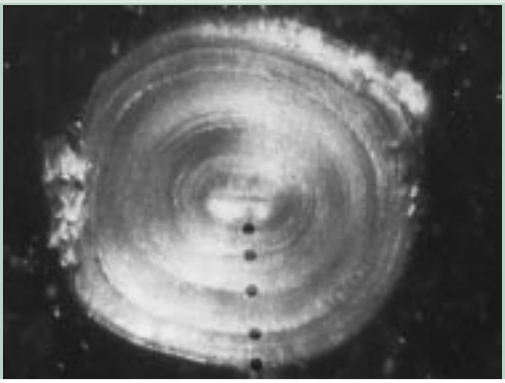


Fig. 12 Cross section of an anglerfish illicium (fishing lure), indicating the positions of annual 'rings' counted for age estimation.

Research at SAMS is focused on age estimation, age validation and stock separation of anglerfish. The age of anglerfish is estimated by counting growth zones in either the ear bones (otoliths) or the fishing lure (illicium) which appear as an alternating series of opaque and translucent rings (Fig. 12). The thicker opaque zones represent periods of faster growth which usually form during the summer in northern temperate waters. If the rings are laid down seasonally then the number of rings corresponds to the age. However, the ring structure can be difficult to interpret because of false rings or checks and it is therefore necessary to validate their annual periodicity. This is being done using micro-increment analysis, which involves counting the rings that are believed to be formed on a daily basis, and also by marginal increment analysis where the nature of the outer edge is followed throughout the year.

Otoliths from different areas have been collected for studies on stock identification using the elemental signature incorporated in the otolith as described above for the OTOMIC project.

JDM Gordon and D Woodroffe (SAMS) and **P Wright** (Fisheries Research Services, Aberdeen)

Deep-water elasmobranchs

Elasmobranchs (sharks and rays) are particularly vulnerable to exploitation and in recent years have been of concern to the United Nations Food and Agriculture Organisation (FAO). The increasing exploitation of deep-water shark species, usually as bycatch, is a particular concern. As part of the FAIR shared-cost project referred to in the introduction, SAMS reviewed the available data on sharks from deep-water trawl surveys to the west of the British Isles. Some of this work was presented at an ICES Annual Science Conference and a report on management considerations of deep-water shark fisheries was subsequently written for FAO. This is a global review of existing knowledge for the species present in each area which summarises survey data and describes the fisheries. It concludes that deep-water sharks have all the problems associated with the management of shallow-water species. Furthermore, monitoring of landings and discards, at least at the species level, has been poor hitherto, and almost all discards will not survive.

In 1999, the University of the Highlands and Islands project funded a PhD studentship at SAMS entitled *Impact of deep-water fisheries on elasmobranch populations of the Northeast Atlantic*. The landings of deep-water sharks were sampled at the port of Lochinver each month throughout 1999, and further elasmobranch material was collected during deep-water research cruises of the research vessels *Thalassa, Challenger* and *Scotia*. In February, the first of a quarterly series of sampling trips on board French commercial trawlers was undertaken. As only two shark species, Portuguese dogfish *Centroscymnus crepidater* and leaf-scaled gulper shark *Centrophorus squamosus*, are landed, a combination of historical survey data, new scientific fishing surveys and data gained on commercial fishing trips is essential for assessing discards and determining the impact of this deep-water fishery on elasmobranch fishes.

JDM Gordon (SAMS) and **P Crozier** (UHIp/SAMS PhD Student)

Invertebrate Biology and Mariculture

Dr Maeve Kelly

The Group's research focuses on the reproductive biology, growth, nutrition and ecology of marine invertebrates, linking closely with the needs of the shellfish industry. While continuing to investigate the reproductive physiology of edible echinoids and gastropods, the research has recently expanded in response to a harmful algal bloom affecting the scallop fishery on the west coast of Scotland.

Commercially viable sea urchin culture

SAMS is co-ordinating a two year EC-CRAFT (Co-operative Research Awards) - funded programme which aims to facilitate the commercial cultivation of the native sea urchin in Scotland. By adopting a fully integrated approach (from brood stock selection, larval hatchery and nursery systems, to perfecting the quality of the roe for market), the research will produce a model for echinoculture methods that will make an industry independent of vulnerable wild stocks. The objectives include:

- The design of a cost-effective, polyculture, grow-out system using existing aquaculture facilities
- Optimising larval culture conditions and maximising survivorship at metamorphosis
- Development of artificial diets incorporating microalgal supplements which enhance both gonad quantity and colour
- Identifying the environmental parameters which control gametogenesis in echinoids

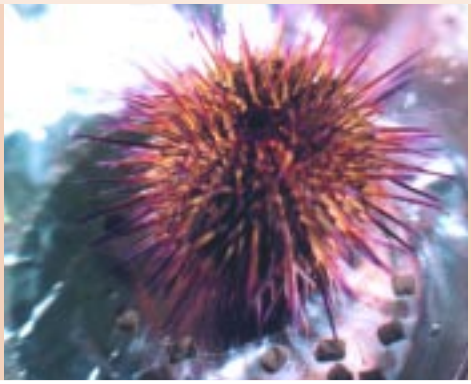


Fig. 13 The urchin *P. miliaris* feeding upon a commercially prepared salmon feed.

Potential for bioaccumulation of chemotherapeutants in polycultured urchins

Our research has shown that the sea urchin *Psammechinus miliaris* thrives in the salmon cage environment (Fig. 13). Polyculture systems therefore offer a cost-effective option for the grow-out phase of urchin production. However, the potential for urchins to bioaccumulate fish medicines must be considered. Accumulation and residue depletion of the antibiotic oxytetracycline (OTC) in the gonads of *P. miliaris* following oral administration was evaluated for urchins of high and low nutritional status, under laboratory conditions (Fig. 14). OTC analyses were carried out by high pressure liquid chromatography (HPLC), after solid phase extraction.

Individual urchins demonstrated considerable variation in drug intake. No significant differences in accumulation and residue depletion of OTC in the gonads were observed between urchins of different nutritional status. On the final day of medication mean OTC residue concentrations were 69.9 µg g^{-1} and 57.95 µg g^{-1} in urchins conditioned on salmon food or macroalgae respectively. Extrapolation indicated that a maximum residue limit (MRL) of 0.1 µg g^{-1} would be reached after a 333.5-day withdrawal period in the gonads of *P. miliaris* fed OTC (29 mg g^{-1}) *ad lib* for a 12-day period.

Such a lengthy OTC residence time in urchin gonads creates practical husbandry difficulties in polyculture of urchins on salmon farms where antibiotics are administered routinely. These results do, however, reflect a 'worst case scenario' for the uptake and decontamination of OTC in the gonads of *P. miliaris*. Data obtained under field conditions are needed to further address these issues and to enable development of protocols to determine maximum residence times and withdrawal periods for urchins maintained in polyculture with fin fish receiving antibiotic medicated feeds.

The potential for urchins to bioaccumulate a recently licensed product, the sea-louse biocide, Calicide, is now under investigation in conjunction with Nutreco ARC.

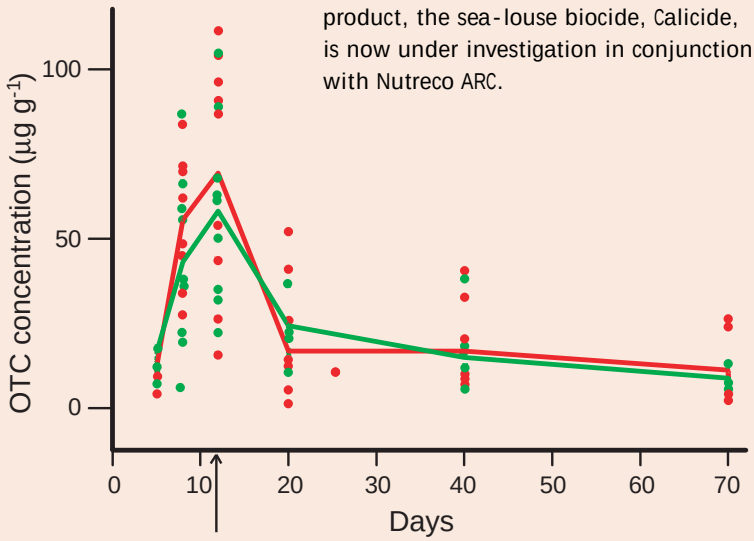


Fig. 14 Persistence of Oxytetracycline (OTC) in the gonads of *P. miliaris* during and after 12 days oral administration of OTC medicated feed *ad lib*. Plotted lines indicate mean values for salmon feed conditioned urchins (–) and *Laminaria saccharina* conditioned urchins (–). Arrow indicates end of OTC administration.

Fig. 15 Dirk Campbell sampling plankton to identify and assess the abundance of *Pseudo-nitzschia* spp at the scallop sampling sites.

Microalgal diet supplements as pigment sources in artificial diets

Fatty acid analysis, using Gas-Liquid Chromatography of artificial urchin diets and the urchins' gonads, showed *P. miliaris* could thrive on diets low in fatty-acids considered essential for other marine species. This has positive implications for the manufacture of a more cost-effective sea urchin diet by excluding expensive raw materials such as fishmeal and fish oils. In addition to an acceptable quantity of gonad, however, the market also requires the gonad to be a bright orange or golden colour. Addressing the problem of variability in gonad pigmentation is therefore an important aspect of artificial diet design.

High Pressure Liquid Chromatography analysis was used to identify the pigment content of urchin roes of a desirable colour and of some carotenoid-rich strains of microalgae. The effect on gonad colour and growth of diets containing two different strains of microalgae (*Phaeodactylum tricornutum* and Tahitian *Isochrysis* sp.) was studied for *P. miliaris*. Both strains of microalgae resulted in higher gonad colour indices than were observed in urchins fed an algae-free control diet, indicating that microalgae have a nutritive value. *P. tricornutum* also had a more pronounced and more rapid beneficial impact on gonad colour. The positive effect of incorporating cultured microalgae into artificial diets has promising implications for commercial echinoculture.

Amnesic shellfish poisoning toxicity in king scallops *Pecten maximus* from the west coast of Scotland

Amnesic shellfish poisoning (ASP), first described from Prince Edward Island, Canada, in 1987, results from the ingestion of shellfish contaminated with domoic acid, a neuro-excitatory amino acid produced by certain species of the pennate diatom *Pseudo-nitzschia* (see p. 52). The incorporation of systematic ASP testing of shellfish into the Scottish waters surveillance programme was initiated early in 1999. July 1999 saw the closure of most of the Scottish scallop fishing grounds in response to the high levels of domoic acid found in scallop tissues. The fishing ban persisted into 2000, causing significant financial hardship for scallop dredging, diving and cultivation industries.

Our research group, in conjunction with the Scallop Association, the DML Culture Collection of Marine Algae and Protozoa and the National Oceanic and Atmospheric Administration (USA) and with funding from Highlands and Islands Enterprise and Highland Council, initiated a project to examine the anatomical distribution and levels of domoic acid in scallop populations over differing spatial scales (Fig. 15). In addition, laboratory-based depuration studies are currently establishing the residence time of the toxin in scallop tissue. The data collected will be used to assist with the development of management strategies to minimise the economic constraints of future ASP events.

MS Kelly, EJ Cook, P Pantazis, M Otero Villanueva and DA Campbell (SAMS), **G McLaughlin** (University of Aberdeen) and **J Youlden** (University of Bradford), in conjunction with Loch Duart Ltd., Red Mills Ltd., Necton Portugal, Xplora Products, Nutreco ARC, Demarne Bros France, The Institute of Aquaculture (University of Stirling), Universidade Catolica Portuguesa, Single Shell Systems, the Scallop Association, NOAA USA and CCAP-DML.

Marine Biotechnology

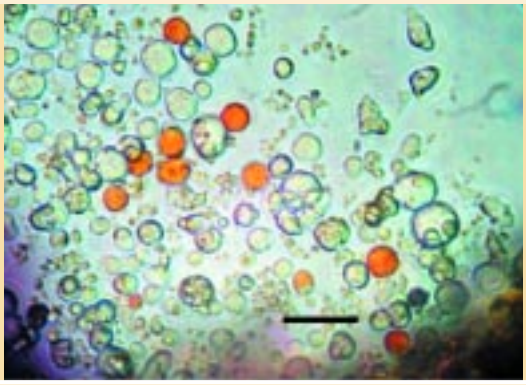


Fig. 16 Cells spilling out of an explant of ascidian stolon. Scale bar = 25 µm.

Securing the supply of marine organisms for natural products research

Marine invertebrates are a useful source of potential pharmaceuticals, particularly for anti-cancer treatments. It is unlikely that wild stocks will be sufficient to meet demand for these new drugs and chemical synthesis would not be economic for many of them. Alternative methods of production are urgently needed. Three areas are being explored in this CRAFT (Co-operative Research Awards) project: (i) Aquaculture of species of interest, (ii) cell culture and (iii) analysis of associated bacteria.

Cell culture methods have been examined both for ascidians (Fig. 16) and echinoderms. Primary cell cultures were established and could be maintained for several weeks. Optimisation of these culture conditions and analysis of media for the production of metabolites is on-going. Proliferation has been observed in explant cultures from sea squirts using bromodeoxyuridine to mark the synthesis of nucleic acids.

Studies have continued on the sponge *Suberites ficus* which is associated with the queen scallop *Chlamys opercularis*. To investigate this association, spat collector bag contents from 1998 and 1999 have been analysed and further bags deployed in 2000, to determine when sponge appears on juvenile scallops and its patterns of distribution. Histological analysis of sponge tissue is being used to investigate the production of gametes and determine some features of the life cycle of this species (Fig. 17). The number of eggs in the tissue increases in the summer months, whereas choanocyte chambers predominate in winter samples. This information will be necessary for the possible aquaculture of this species, and to facilitate the settlement of the sponge on *C. opercularis*, which limits other more destructive biofouling.

C Moss, JD McKenzie and C Bavington
(SAMS) in conjunction with Instituto Biomar S.A., Loch Fyne Seafarms Ltd., PharmaMar S.A., Alvito GmbH, Museum National d'Histoire Naturelle (Paris)

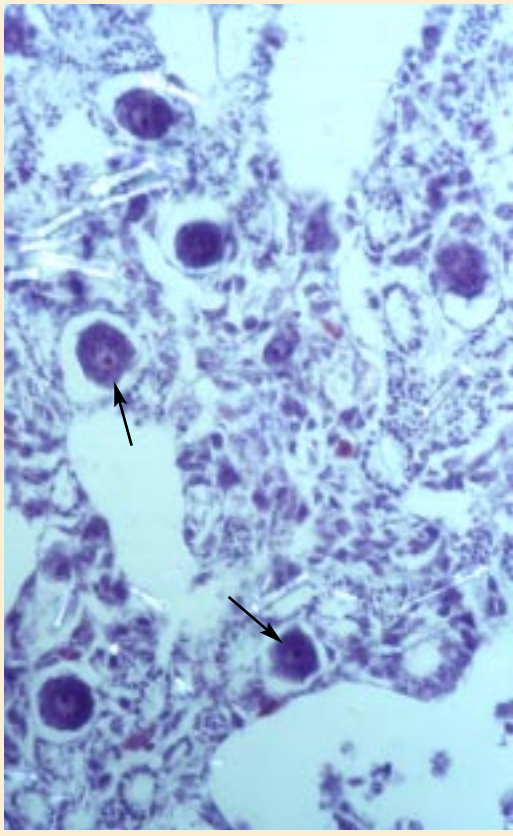


Fig. 17 Histological section through *Suberites ficus* from Loch Fyne showing developing oocytes (arrowed) approximately 30 µm in diameter.

Marine carotenoids as antioxidants and inhibitors of phospholipase activity

Carotenoids are being increasingly investigated as important components of diet, exerting powerful influences on human health. They are particularly common and diverse in marine organisms, producing many of the colours seen in marine invertebrates, though their functions are usually obscure. Whilst marine invertebrates do not directly manufacture carotenoids themselves, they are responsible for modifying the structure of dietary carotenoids, producing new structures.

There is growing recognition that many psychiatric disorders may have their origins in metabolic dysfunction. This project is part of a wider study into the clinical use of antioxidants and phospholipase inhibitors in the treatment of various psychiatric illnesses. Oxidative stress in neuronal membranes has been reported in many psychiatric disorders including schizophrenia. Adjunctive treatment with antioxidants (such as vitamin C, vitamin E and carotenoids) may inhibit further oxidative injury in brain cells, thereby preventing further possible deterioration of psychiatric illnesses.

At Dunstaffnage, human monocyte cultures have been successfully established as model systems to study the effects of carotenoids. Preliminary results suggest that mixtures of carotenoids give better protection against oxidative stress and improve recovery of stressed cells than do single carotenoids or vitamin C.

O Obajimi and JD McKenzie (SAMS) and
I Glen (Highland Psychiatric Research Foundation)

Microbial ecotoxicology

The toxic effects of common laboratory organic compounds have been used as a model for environmental stress during the development of an ecotoxicology assay. Bacteria, selectively isolated from marine environments around the western coast of Scotland and the Baltic coast of Sweden, have been used as the assay organism. The influence of such chemicals upon parameters including bacterial growth, DNA replication and metabolic activity has been analysed using an array of stress indicators. The quantification of the level of DNA synthesis using a BrDU (Bromodeoxyuridine) Cell Proliferation Assay was performed. The level of incorporation of BrDU into the replicating bacterial genome was directly correlated with the amount of chemiluminescence detected by an adapted microplate reader. The chemiluminescence originates from the enzymatic breakdown of luminol substrate by peroxidase conjugated to monoclonal antibodies with a high binding specificity to BrDU. Although technical difficulties were encountered, mainly due to the fact the assay was designed for eukaryotic cell division, the results showed a reduction in DNA replication as the concentration of toxins, including ethanol, increased.

M Hart and JD McKenzie (SAMS),
J Gabrielson and I Kuhn (Karolinska Institute)
in association with PhenePlate, Applied Maths BVBA, Don Whitley Scientific, Scottish Environmental Advisory Services and The Scottish Environment Protection Agency

Microbial Ecology

Dr Ray Leakey

The planktonic microbial community plays a major role in the transfer of energy and nutrients through the marine food web.

Planktonic algae are responsible for the bulk of marine primary production. This algal production may then be consumed, either by unicellular protozoa or larger invertebrate zooplankton. In addition, algal cells excrete dissolved organic carbon which is consumed by planktonic bacteria. These bacteria may then themselves be consumed by protozoans, which in turn may be grazed by the larger zooplankton. Planktonic micro-organisms therefore comprise a complex and productive community and are central to a variety of important biogeochemical processes.

Current microbial ecology research activities focus on the role of planktonic micro-organisms in temperate, tropical and polar waters. One project is based on field experiments in Loch Fyne with the wider goal of enhancing the management of fish farming activity. Two projects, one of which is described below, are based on Antarctic field studies. In addition, three new projects have been established. One of these will investigate the role of planktonic algae in stimulating foraging by commercially reared halibut larvae. The other two, one of which is described below, are concerned with the role of planktonic micro-organisms in coastal eutrophication and pollution impact.

Interannual variability of microbial biomass in Antarctic coastal waters

This work aims to establish baseline interannual information on the abundance and biomass of planktonic algae (diatoms) and protozoans (ciliates and dinoflagellates) in Ryder Bay, offshore from Adelaide Island in the Antarctic peninsula region. The study forms part of a long-term programme monitoring the oceanography and biogeochemistry of Ryder Bay. It will provide the first interannual information on marine heterotrophic microbial biomass from the Antarctic and will help identify changes in the Antarctic planktonic community due to climate change.

Preserved water samples collected at 15 m depth between June 1998 and February 1999 have now been analysed. All three microplankton groups (diatoms, ciliates and dinoflagellates) exhibited clear annual cycles of low winter and high summer values (Fig. 18). Maximum diatom biomass was observed in early February while dinoflagellate and ciliate biomass increased into late February. This delay in maximum protozoan biomass, relative to that of the total algal community, may be due to more subtle changes in the species composition of their algal prey. The seasonal pattern in microbial biomass was similar to that observed further north in warmer Antarctic waters near Signy Island. However, maximum values for each taxonomic group were 2–3 times greater in Ryder Bay than at Signy Island. Full analysis of the first year's data awaits the return of further samples from the Antarctic in June 2000. This will be followed by further studies during the next five years to build up a complete interannual data set.

R Leakey (SAMS), A Clarke and E Roberts
(British Antarctic Survey)

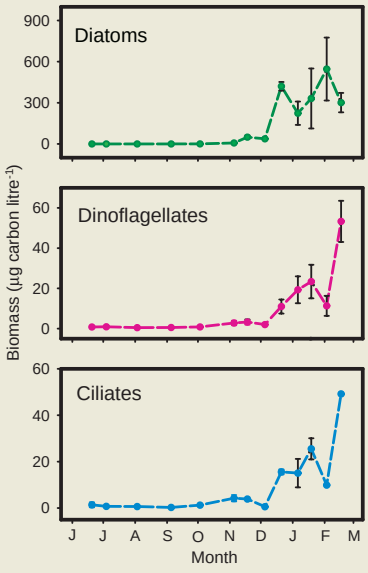


Fig. 18 Microplankton biomass in Ryder Bay, Antarctica.

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Fig. 19 Microbial fieldwork in Korangi Creek, Pakistan.

The ecology of heterotrophic micro-organisms in Pakistani coastal waters

This new project is investigating the ecology of micro-organisms in polluted coastal waters off Pakistan. The research forms part of a British Council higher education link between SAMS and the University of Karachi, which will focus on the assessment and management of pollution in Pakistani coastal waters.

The coast in the vicinity of Karachi is characterised by hypersaline tidal creeks with extensive mangrove forests. These creeks are used as natural harbours and much commercial and industrial activity has grown up in and around them. As a result they are subject to high inputs of organic and inorganic pollutants which may be damaging the mangrove forests and contaminating locally caught fish.

The study will determine the abundance and biomass of planktonic micro-organisms, along with other biogeochemical variables, at stations of differing proximity to pollution inputs in Korangi Creek near Karachi (Fig. 19). This information will help to establish the impact of the pollutants on the planktonic environment and provide baseline data against which to monitor changes in pollution impact. Initial samples, collected in March 2000, reveal much lower microbial biomass and diversity in the upper reaches of the creek relative to less polluted waters nearer the open sea.

R Leakey (SAMS),
J Siddiqui and M Zaib-un-Nisa
(Centre of Excellence in Marine Biology, University of Karachi)

Zooplankton Dynamics

Dr Geraint Tarling

The main focus of the Zooplankton Dynamics Group during the year has been the interaction between physical factors, the behaviour of meso- and macro-zooplankton and modelling involving physiological parameters. The European MAST 3 'PEP' Project came to an end in July and is being followed by an intensive 12-month field sampling campaign in the Clyde Sea Area to provide information on the population dynamics, production and behaviour of zooplankton that will assist with the effective management of the region.

Data are being collected with moored and ship-based acoustics (Fig. 20) as well as with multinets, and then integrated into models to predict vertical migration patterns and the effect of currents and current shear on dispersion. Field campaigns have also involved the measurement of the 'active flux' of carbon and nitrogen that results from diel vertical migration. Other projects that have been started this year include a study on the effect of de-lousing chemicals on zooplankton communities in Scottish sea-lochs.

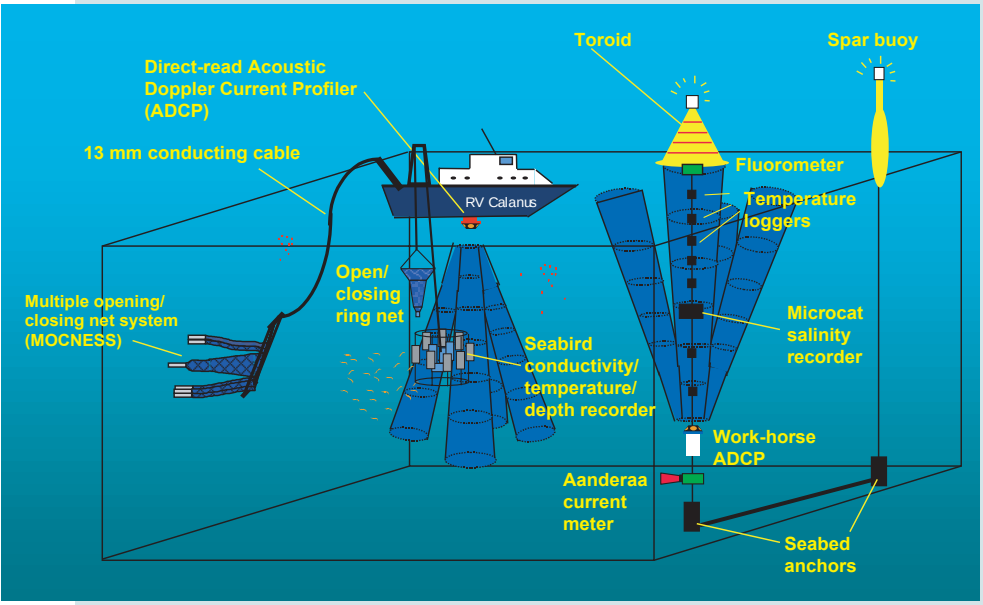


Fig. 20 Biophysical sampling plan used during the year-long study of the Clyde Sea Area between June 1999 and July 2000.

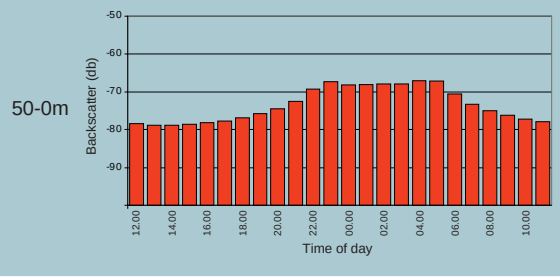
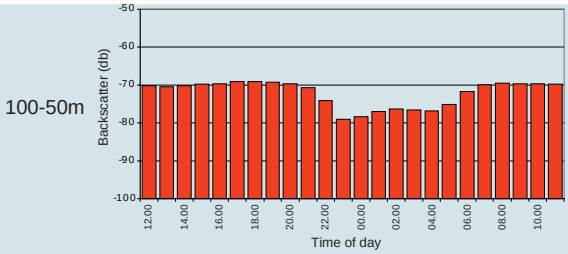


Fig. 21 Backscatter data collected between 24/6/99 and 8/8/99 by the Acoustic Doppler Current Profiler moored in the Clyde Sea Area. Data have been averaged over the study period and plotted on a 24 hour time scale. Backscatter levels between 2200hrs and 0600hrs rose in the 50–0 m depth interval and fell correspondingly in the 100–50 m depth interval as a result of the diel vertical migration behaviour of zooplankton. The small fall in backscatter in the 50–0 m depth interval between midnight and 0300hrs is considered to be the result of "midnight sinking".



The Clyde Sea Area time-series

The Clyde Sea is an area of economic importance for both fisheries and industry. One novel aspect of the 12-month sampling campaign that started in June was the inclusion on the SAMS permanent mooring of an Acoustic Doppler Current Profiler (ADCP), capable of collecting information on the biomass and behaviour of zooplankton as well as on the currents that affect their distribution patterns. Results for the first six months of this time-series have already provided some new insights, especially with regard to how zooplankton migrate vertically from their day-time position in the deep to the feeding layers at the surface (Fig. 21). One particular surprise was the high downward velocities that were recorded soon after most of the community had migrated to the surface layers after dusk. Preliminary results suggest that these animals were euphausiids about to moult, a process they must go through approximately every ten days (Fig. 22). Moulting in the deep would reduce the risk of cannibalism whilst they are in a flaccid and vulnerable state.

Fig. 22 The head of Northern krill *Meganyctiphanes norvegica* showing the antennular penduncle which is used to classify moult stage through examining the degree of separation in the new (inner) and old (outer) cuticle.

Modelling vertical migration behaviour

The aim of developing behavioural models is to understand 'why' an animal behaves in the way it does. Diel vertical migration behaviour is a widespread phenomenon common to a large number of zooplankton species but there is little agreement as to the cause of the behaviour. Some of the more popular hypotheses include the avoidance of predation, the maximisation of feeding rate and the minimisation of metabolic loss. Through modelling it is possible to compare these hypotheses in order to determine which strategy best explains the observed behaviour. A model was developed for the euphausiid, *Meganyctiphanes norvegica*, which allowed the animal to balance the risk of predation against energy gain, under the constraint that it must eat a sufficient amount of food to satisfy its metabolic needs. Two contrasting environments, the Clyde Sea and the Kattegat, were parameterised in order to run the model and the predicted vertical migration patterns were compared with observations made at the two sites. The model was relatively successful in simulating the diel vertical migration patterns seen in both environments, and sensitivity analyses revealed that the most important constraint on behaviour was the distribution of food through the water column. The development of the model was also instructive in identifying the relative importance of the various parameters measured in the field, as well as the most appropriate levels of temporal and spatial resolution at which to sample.

Zooplankton Dynamics

Active flux

Knowledge of the flow of materials through marine systems is a key element in the development of climate-change models and the principal goal of major oceanographic research programmes such as JGOFS (Joint Global Ocean Flux Study). A particularly important aspect is the rate at which key elements, such as carbon and nitrogen, are lost from the surface mixed layer. It has traditionally been believed that the major route is through the passive sinking of this material, but recently there has been increasing evidence that zooplankton may act as a short-cut, by transporting material rapidly from the surface to the deep as they perform diel vertical migration. This is because zooplankton mostly eat at the surface and excrete or defaecate at depth, so causing an 'active flux' of material to the ocean's interior. Measurements of this flux have been achieved by collecting euphausiids (*M. norvegica* and *Thysanoessa raschii*) and copepods (*Calanus finmarchicus*) at dusk, just before they start eating, and at dawn, before they re-enter the deeper layers, and then calculating the net difference in carbon and nitrogen levels. Sampling has been undertaken on five cruises in the Clyde Sea Area in all seasons, and this technique will shortly be applied to fjords in New Zealand and also under more oligotrophic conditions off Bermuda. It is envisaged that these measurements, which are among the first of their kind, will provide important contributions to global flux models.

The effect of delousing chemicals on zooplankton communities

The infestation of salmon by sea-lice (caligoid copepods) is a major economic problem in Scottish salmon farms and various chemicals are regularly used as delousing agents. Environmental concerns about the effect of this practice on the sea-lochs where the farms are based has led the Ministry of Agriculture, Fisheries and Food and the Veterinary Medical Directorate to commission a study on the impact of de-lousing chemicals on the marine ecosystem. The Zooplankton Dynamics Group is studying the impact on zooplankton communities as part of a multidisciplinary team spread between three Laboratories. The study will ultimately monitor conditions at farms in three sea-lochs that differ in their hydrodynamic characteristics. Different chemicals are used at each site and are applied either as baths, which result in a large release of chemicals over a short period of time, or in the fish feed, which results in a chronic release at relatively low levels. So far, one site in Loch Sunart has been sampled during three bath treatments with Cypermethrin.

GA Tarling, JBL Matthews and KJ Willis (SAMS),
T Jarvis (UHIp) and R Saunders (University of Bradford)

Dr Angela Hatton

Influence of light on the biogeochemical cycle of dimethylsulphide

Dimethylsulphide (DMS) is the most abundant volatile sulphur compound in seawater and affects natural marine ecosystems in at least three ways.

Firstly, high concentrations of DMS are toxic and malodorous and can lead locally to environmental problems. Secondly, atmospheric oxidation products of DMS not only contribute to acid precipitation, but may also influence climate due to the formation of cloud condensation nuclei. Thirdly, DMS is involved in the transport of sulphur from the oceans to land and therefore plays a major role in the global sulphur cycle. DMS is considered to be formed from the breakdown of dimethylsulphoniopropionate (DMSP), a salt which is produced by phytoplankton to maintain their osmotic balance in seawater.

It is now thought that the liberation of DMS from intracellular DMSP is relatively insignificant and zooplankton grazing may be a factor controlling the production of DMS. It was also assumed that the oxidised form of DMS, dimethylsulphoxide (DMSO) would be present in seawater. Although DMSO has now been measured in marine waters, little progress has been made regarding the origin and fate of this compound. Research at SAMS is investigating the pathways involved in the production and turnover of DMS, to establish whether anaerobic processes occur in surface waters and to assess how these findings relate to other biogeochemical cycles.

Of the numerous production and utilisation pathways proposed for DMS, the relative importance of some, such as photo-oxidation, is poorly quantified. Previous research had suggested that DMS might be removed from the water column via photochemical oxidation leading to the formation of DMSO. However, these conclusions were based on the removal rate for DMS and no measurements for DMSO were taken. A number of photo-oxidation experiments have now been conducted using ultra-filtered surface seawater. Samples were incubated under natural light, UV filtered conditions and in the dark for up to eight hours and analysed for changes in DMS and DMSO concentration. Results clearly showed light-dependent removal of DMS with an average loss rate of 2.72 nM day^{-1} for natural light and 1.12 nM day^{-1} for UV filtered samples. No DMS loss was observed in dark controls (Fig. 23). Although these results appeared quite straightforward, data generated for DMSO production rates appeared much more erratic, showing no correlation with DMS removal rates, and in many cases appearing to demonstrate light-dependent removal of DMSO. This removal rate also appeared to be affected by the level of dissolved organic carbon (DOC) present in the water.

Although it now seems evident that photolysis represents a significant process whereby DMS is removed from surface waters, the part DMSO plays in this process is still very much in question. More work is required to investigate the photolysis and photogeneration of DMSO and to establish the importance of DOC.

A Hatton (NERC Research Fellow)

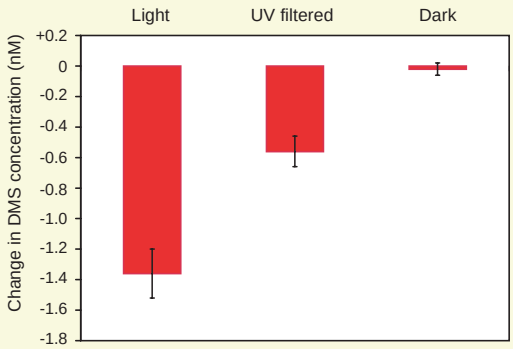


Fig. 23 The average change in DMS concentration in samples incubated for eight hours under light, UV filtered and dark conditions. Results clearly show light-dependent removal of DMS.

Production of DMSO in sediment trap material

The main aim of this work was to establish whether anaerobic micro-environments, such as zooplankton faecal pellets, represent potential sites for the oxidation of DMS to DMSO. Previous work had demonstrated that any DMSP in faecal pellets decreased over time, but there appeared to be no increase in dissolved DMSP or DMS, indicating that the particulate DMSP must be metabolised to other sulphur compounds. To investigate the fate of DMSP in faecal pellets and to assess if DMSO is generated during this process, sediment traps were deployed in the northern North Sea during June 1999 for a maximum of 24 hours. After recovery, samples were analysed for DMS, DMSO and DMSP. Any remaining trap material was incubated in the dark at *in situ* seawater temperature for a maximum of 110 hours. Results proved extremely exciting. Not only were high levels of particulate and dissolved DMSO found in all the traps, but experiments also showed that DMSO was generated within the trap material. Figure 24 shows the relative quantities of DMS, DMSO and DMSP in both the dissolved and particulate fractions from an incubation experiment. Results clearly demonstrate increasing DMSO concentrations in both fractions, coincident with decreasing DMSP levels. Levels of DMS appeared to increase initially, but declined again over time. Furthermore, the concentration of total sulphur decreases over time, suggesting that although DMSO is generated it cannot account for all the DMSP and DMS lost. It has previously been suggested that methanogenic bacteria may be present in zooplankton faecal pellets and that DMS may represent a potential substrate for these bacteria. It is therefore feasible that methanogenic bacteria are responsible for removal of DMS from these sites, resulting in the loss of total sulphur.

A Hatton (NERC Research Fellow)

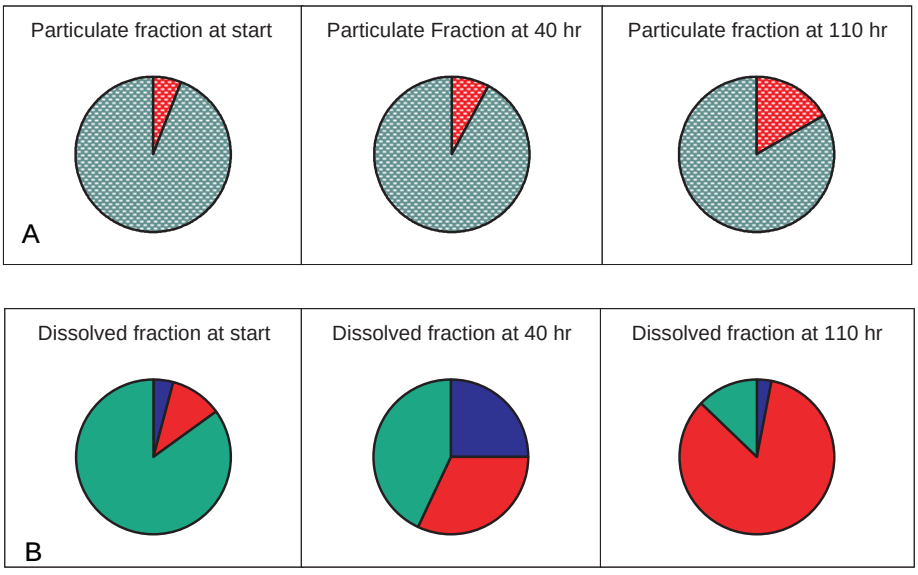


Fig. 24 The relative quantities of DMS (blue), DMSO (red) and DMSP (green) in the particulate (A) and dissolved (B) fractions of sediment trap material incubated over a 110 hour period. Results clearly show an increase in DMSO in both fractions over time. The concentration of DMS also increases initially, but falls back to the original level.

Dr Keith Davidson

University of Highland and Islands project BSc marine science degree team

The four marine science lecturers have completed training in delivery of modules over the UHIp electronic network and will start teaching the new degree course in September 2000. They are also actively involved in UHIp research-related activities, through membership of the Staff Development, Research, Research Degrees and Research School committees and through the hosting of the Board of the Research School of Natural Systems Sciences. This provides SAMS with a significant influence in the development of scientific research activities within the UHIp.

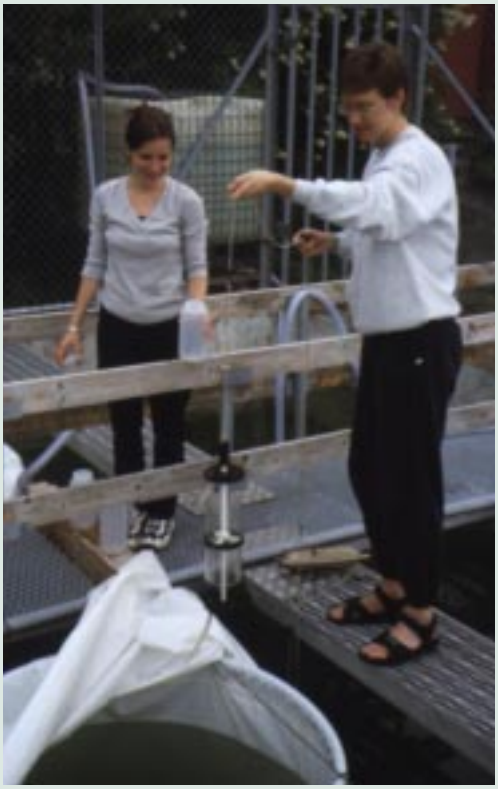


Fig. 25 Sampling mesocosms at the Trondheim Marine Systems Large Scale Facility, Norway.

Research is underway on the following topics

Dynamics and modelling of algal and protozoan populations

Research has concentrated on investigating factors that influence the growth of phytoplankton and their protozoan predators. Three projects are currently underway: the study of carbon-nitrogen (CN) budgets and trophic selections within marine microbial food webs in laboratory microcosms, as part of the NERC Plankton Reactivity in the Marine Environment (PRIME) Thematic Programme; the influence of nitrogen:silicon ratios on diatom growth dynamics, funded by the EC (see below) and finally, a project to study the influence of microzooplankton on microbial food webs using computer models of different levels of sophistication, as part of the NERC Marine Productivity Thematic Programme.

Phytoplankton blooms in coastal waters are often dominated by diatom species. Nitrogen (N) and silicon (Si) are essential nutrients for diatom growth. While Si supply to coastal waters has remained approximately constant over recent decades, increased anthropogenic input of N has occurred, resulting in a shift in inorganic N:Si ratios. Understanding the role of N:Si ratios in determining diatom growth rates is now of particular importance if we are to elucidate the complex interactions which determine the magnitude, composition and timing of phytoplankton blooms.

In June 1999, nutrient enrichment mesocosm experiments were conducted in seven 1500 litre enclosures (Fig. 25) with varying N:Si ratios using a natural planktonic assemblage from Trondheimsfjord, Norway, dominated by *Skeletonema costatum*. Standard "Redfield" theory predicts that N and Si should be taken up by phytoplankton in a ratio of 1:1. The nutrient in the least relative supply will then limit

Dr John Howe

phytoplankton growth. However, experiments using a variety of inorganic N:Si ratios (1:2, 1:1, 2:1, 4:1) indicated that Si limitation occurred only at the highest N:Si ratio of 4:1. Nitrate exhaustion produced a cessation of Si uptake, while under Si exhaustion, N uptake continued although at a slower rate than pre Si exhaustion. In both cases, as particulate organic carbon increased subsequent to limiting nutrient exhaustion, differences in the C:N ratio of the organic material were observed.

These results indicate that high anthropogenic N loading may be required to produce Si limitation of diatom growth in coastal waters. This in turn may lead to changes in phytoplankton community composition with consequent effects on higher trophic levels.

K Davidson (SAMS/UHIp),
L Gilpin (Napier University) and
EH John (CCMS Plymouth Marine Laboratory)

The marine geomorphology of Loch Etive

Loch Etive in Argyll on the west coast of Scotland, is a 30 km long, up to 145 m deep sea loch of glacial origin. A unique side-scan sonar image covering an area of 19.5 km^2, with accompanying bathymetric data of the upper basin of the loch, has been collected by Ultra Electronics using RV *Calanus*. This is the first detailed survey of the upper basin since 1861 and the image (Fig. 26) illustrates the sedimentary processes that have been active in the loch since the end of the last glaciation, approximately 10000 years BP. The new bathymetry reveals the complex physiography of the loch with the deepest (>100 m) regions confined to the SW with slope angles from 5-15°. Towards the head of the loch water depths are shallower, with <50 m common and the loch floor is also smoother with slope angles of 2-5°. High backscatter areas on the image correspond to regions of exposed outcrops of *in situ* granite, with localised glacial erratics on the loch floor. Low backscatter areas occur in the deeper-water basins containing fine-grained sediments. Other features observed are submarine cliffs, downslope creep of water-laden sediments on the steeper loch slopes, and outwash submarine fans from rivers. This project is the key stepping-stone to future long coring and high-resolution seismic surveying of the loch. The ultimate goal is to retrieve long-term climate records from Loch Etive; one of the targets of the CCMS Restricted Exchange Environments Core Strategic Programme (REEs).

JA Howe and ME Inall (SAMS/UHIp),
J Overnell (CCMS-DML) and
A Wilby (Ultra Electronics Ocean Systems)

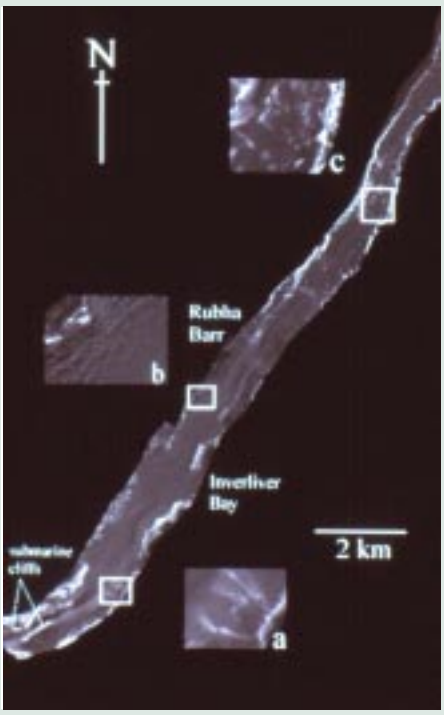


Fig. 26 Side-scan sonar survey of upper Loch Etive. Insets: (a) Outwash fans from the River Noe; (b) Sediment creep, due to gravity-induced mass wasting of water-laden soft sediment on the steep slopes; (c) Boulders on the loch floor, possibly a result of glacial retreat or post glacial rockfall.

Dr Mark Inall

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Fig. 28 David Ellett deploying hydrographic equipment from RRS *Challenger*.

Marine physics

Field studies formed the foci of research over the year. During June and July of 1999, the observational phase of a NERC–funded project was undertaken in the Clyde Sea on the Laboratory's RV *Calanus* and the *Prince Madog* (University of Wales, Bangor). SAMS interests centre on the role of internal waves in deep water renewal. These waves can be detected on satellite images (Fig. 27).

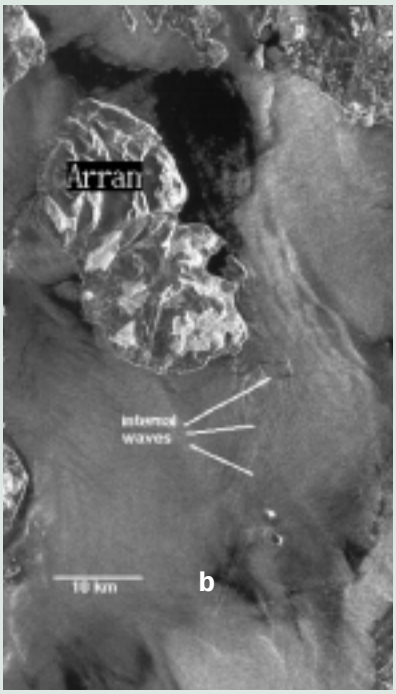

Fig. 27 Synthetic Aperture Radar Image of the southern Firth of Clyde from the ERS2 satellite. The light and dark bands indicated are the surface manifestation of internal waves generated by the submarine sill which runs from Arran to Ailsa Craig. Feature b is the internal wake of the Seacat ferry. The image size is 30 km by 30 km and was kindly provided by the Defence Evaluation and Research Agency, Farnborough.

The second area of study has been a collaborative attempt to continue the long time-series of hydrographic observations at 30 stations between Scotland and Rockall, initiated by David Ellett (Fig. 28) in 1975. Since David's retirement, the Southampton Oceanography Centre (SOC) has occupied the stations (Fig. 29) every year. The principal measurements at each station are temperature and salinity from the surface to the bottom. Water samples are also taken at various depths for biological and chemical analyses. Current meter moorings have been deployed at four stations along the line, one inshore (Y), one at the Shelf Break (R) and two in the deep water either side of the Anton Dohrn Seamount (F&M). The instruments are deployed at various depths and make hourly measurements of temperature, current speed and direction.

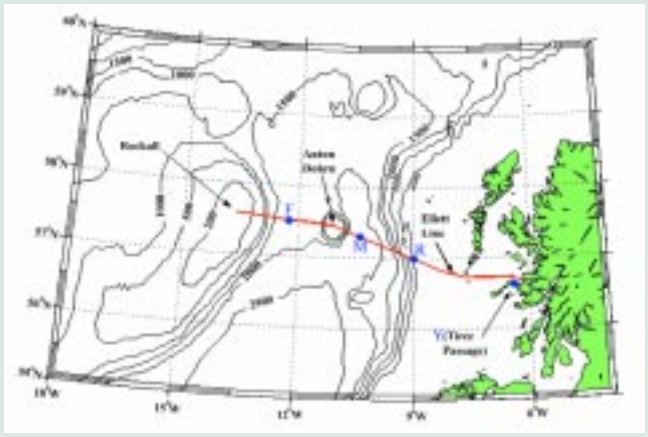

Fig. 29 Chart showing the position of the Ellett Line to the west of Scotland.

These measurements have helped our understanding of how the waters that lie to the west of Britain influence our climate. The role of the Gulf Stream is less important than is commonly suggested and the key to our mild winters is the depth of winter mixing, largely controlled by deep convection and the frequency and severity of storms, thereby releasing heat into the atmosphere. David Ellett compared this to a fan-assisted storage heater.

During the last year the line was occupied four times though due to adverse weather conditions, including hurricane-force winds during January, two attempts were only partially successful. The line is now being maintained as a joint project involving DML, SOC and Fisheries Research Services (FRS), Aberdeen, and involves a new UHIp PhD studentship, in collaboration with FRS. This will examine high-frequency variability in north-east Atlantic topographic flows.

Dr Axel Miller

These results build on earlier observations taken by the weather ships. Such long running time–series observations are rare but are crucial to our understanding of the variability in the observations. The late nineties have seen a warming phase similar to the one observed in the late fifties, though the significance of the present warming episode is unclear. What is clear, however, is that our understanding of, and therefore our ability to model the thermohaline circulation requires the maintenance of such time-series.

ME Inall (SAMS/UHIp),
C Griffiths (CCMS-DML),
S Cunningham (James Rennell Division of the Southampton Oceanography Centre) and
W Turrell (Fisheries Research Services, Aberdeen)

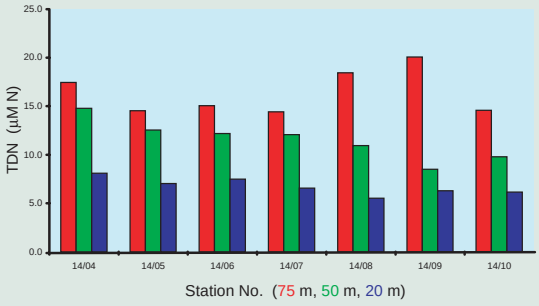

Fig. 30 Concentrations of total dissolved nitrogen (TDN) and dissolved organic nitrogen (DON) where TDN=DON, at seven stations along an oceanic transect in the northern North Sea, on 14th June 1999. Concentrations of inorganic nitrogen nutrients were in the nano-molar region at all depths for all stations.

Biogeochemistry

A SAMS bursary, together with a grant from the Nuffield Foundation *Awards to Newly Appointed Lecturers* programme, allowed participation in the CCMS DISCO (Dimethyl Sulphide Biogeochemistry within a Coccolithophore Bloom) cruise during June 1999. The DISCO project aims to establish a link between the marine carbon and sulphur cycles by following the dynamics of a coccolithophore bloom and its influence on marine biogeochemistry. This work is complementary to the studies undertaken by SAMS during *Phaeocystis* sp. blooms in Dutch waters, under the EU-ESCAPE programme.

The total oceanic dissolved organic matter (DOM) pool holds 200-800 Gt carbon, equivalent to the amount held as atmospheric CO2. The accumulation of DOM during phytoplankton blooms is a complex balance between production and consumption processes which can only be understood through interdisciplinary field studies incorporating quantification of major sources (i.e. primary production, zooplankton grazing, physico-chemical particulate organic matter (POM) to DOM conversion, photochemical transformation) and sinks (i.e. bacterial turnover, DOM-POM adsorption, photochemically-induced oxidation).

DISCO aims to decipher some of these processes in relation to the DOM dynamics, through: (1) determining the temporal dynamics of bulk dissolved organic carbon (DOC) and dissolved organic nitrogen (DON); (2) investigating the dissolution of organic matter in sediment traps, as a potential mechanism for the amelioration of the sinking carbon flux below the photic zone and (3) collaborative temporal incubation experiments to investigate dynamics of DOC and DON reservoirs (i) relative to carbon monoxide production under varying light conditions, (ii) through assessment of DOC consumption in parallel with net community respiration, and (iii) by participating in micro-zooplankton grazing experiments with the associated release of DOC.

Preliminary data from total dissolved nitrogen analysis showed that, where inorganic nutrients were detectable only at nano-molar concentrations, the total dissolved nitrogen was almost entirely in the organic phase. This is exemplified in data from vertical sampling along an oceanic transect (Fig. 30) showing relatively high (micro-molar) total dissolved nitrogen concentrations against a background of negligible (nano-molar) inorganic nitrogen at all stations.

A Miller (SAMS/UHIp),
A Hatton (NERC Fellow),
R Ling, C Robinson, M Zubkov, S Archer and C Stelfox (CCMS-PML)

A successful tern colony.

Marine ornithology

From its start in 1987, research has shown that feral American mink have been causing widespread annual whole-colony breeding failures of ground-nesting seabirds on small islands along the west coast of Scotland. The groups chiefly affected are gulls, terns, shags and black guillemots. The ecological effects have been considerable: several sealochs and sounds have lost all or most of their breeding seabirds and regional totals of some gull and tern species have roughly halved.

To combat these losses, and particularly to save the more important of the surviving tern colonies, control of mink at selected sites has been undertaken in recent years. After a promising pilot study at two sites in 1995, the technique was successful in 1996 at eight of 11 sites where mink were removed, and at 12 of 14 sites in 1997. In 1998 seabirds bred successfully at all 20 sites where the method was applied. In 1999, mink were removed from 24 colony sites in ten sealochs or sounds, and seabirds bred successfully at 23 of the 24 sites. Comparison with unprotected colonies showed that mink removal raised the average productivity (number of young fledged per breeding pair) by factors of two or more, depending on species (Table 1 overleaf).

One of the sites included in this work is the largest colony of Common Terns in the British Isles, with 772 pairs in 1999 or over 5% of the British Isles total. It was attacked by mink first in 1989 and again several later years, so attempts were made from 1992 to control mink at this nationally important colony. In 1998 the site was designated a Special Protected Area under the European Union Birds Directive, and the accompanying legislation requires the UK to take active conservation measures. Annual mink control at the colony is proving effective and, in 1999, at least 500–600 young fledged. Most other tern colonies where mink were controlled also bred successfully. In contrast, as in the two previous years, most unprotected sites lost all their young because of mink predation (four of five colonies of common terns and two of three colonies of arctic terns: see Table 1). Another achievement in 1999 was the return of black-headed gulls, common terns, arctic terns and black guillemot to breed at Eilean Inshaig in Loch Craignish. This site is now protected from mink by local people, following several years when it was abandoned by seabirds after whole-colony breeding failures in 1992, 1993 and 1994, all caused by mink predation.

In 1999 mink again caused numerous whole-colony breeding failures of herring gulls over a wide area. By comparing these with protected colonies, it was estimated that mink reduced the overall local productivity of this species by 53% in 1999 (compared with 68% in 1998 and 53% in 1997). These annual mink-caused breeding failures, and the consequent slow but profound decreases in populations of these gull and tern species, are unlikely to be noticed unless numbers and breeding success are monitored each year at a suitable number of colonies.

JCA Craik, SAMS Honorary Fellow

Report from the SAMS Honorary Fellows

Table 1 Effect of mink control on productivity of gulls and terns in 1999

For each species, first line gives results at colonies where mink were removed before the breeding season, second line gives the same results at colonies where mink were not removed, and right-hand column gives increase in productivity achieved by mink control.

Species	No. of pairs (No. of colonies)	No. fledged (No. of colonies where none fledged)	No. fledged/pr	Increase factor
Common Gull	828 (18)	510 (1)	0.616	2.4
	506 (26)	132 (11)	0.261	
Herring Gull	1700 (7)	1373 (0)	0.808	2.1
	6492 (42)	2465 (14)	0.380	
Common Tern	1047 (9)	690 (0)	0.659	6.2
	151 (5)	16 (4)	0.106	
Arctic Tern	98 (5)	72 (0)	0.73	24
	67 (3)	2 (2)	0.03	

JCA Craik, SAMS Honorary Fellow

Geology

An overview of submarine hydrothermal mineralization on the Izu-Bonin Arc, based mainly on an analysis of the results of 43 dives of the Shinkai 2000 submersible, was conducted while working at the University of Tokyo. By far the most extensive deposit is the Sunrise deposit at Myojin Knoll, one of the largest submarine volcanic massive sulphide deposits so far discovered with an estimated mass of about 9×10^6 tonnes. It was concluded that the Izu-Bonin Arc could profitably serve as a natural laboratory for the long-term monitoring of seismicity, volcanism and submarine hydrothermal activity on the seafloor.

Investigations of heavy-metal pollution of marine sediments from the Polish EEZ were carried out in collaboration with Professor Piotr Szefer at the Medical University of Gdansk. So far, Gdansk Bay, Puck Bay and the Vistula Lagoon have been studied and future work will concentrate on Szczecin Lagoon.

Work is also being conducted with Professor Costas Papavassiliou at the National University of Athens on the nature and origin of the Vani manganese deposit on Milos Island. This is a low-grade hydrothermal manganese deposit which was mined between 1890 and 1928 producing over 220,000 t of manganese ore. The deposit has a number of unique features. In particular, the principal manganese minerals present are pyrolusite, ramsdellite and the isomorphous series cryptomelane-hollandite-coronadite. This results in the deposit being anomalously enriched in a number of elements, particularly barium, lead and zinc, compared to other hydrothermal manganese deposits.

G Glasby SAMS Honorary Fellow, EU Visiting Professor at the University of Tokyo and EU Marie Curie Senior Fellow at the University of Athens

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Fig 31 The new Data Warehouse building under construction within the inner quadrangle of the Laboratory.

Data Warehouse progress report

The Data Warehouse, which was developed to provide IT services to each of the 13 University of the Highlands and Islands project (UHIp) academic partners, has continued to make progress, with funding from the Millennium Commission, the European Regional Development Fund and CCMS.

Following the original installation work carried out in March 1999, the hardware based at DML now includes a SUN Enterprise 3500, two IBM NetFinity 5000 systems, two IBM NetFinity 5500 systems, three SUN Ultra 10 systems, one SUN Ultra 5 and RAID-configured disk packs. Various applications, including the UHIp Library Management System, Student Information System, E-mail, Directory Services and Website have been implemented on the above servers.

The Library Management System, a single catalogue of resources which also identifies local resources, continues to grow and a bi-lingual interface is to be installed. Inverness College has been using the circulation and cataloguing modules since December and Moray, Perth, North Atlantic Fisheries (Shetland) and Thurso Colleges are at the data-loading stage. The library catalogue can now be accessed over the world-wide web: www.uhi.ac.uk.

For the future, there is extensive development potential within the Data Warehouse Project for both SAMS and NERC. Areas of interest include the consolidation of the IT-services which are common to both SAMS/UHIp and NERC, continued expansion of the current range of available IT-services in order to attract and support new partners and, finally, promotion of the SAMS Data Warehouse as a centre of expertise with which partners can collaborate for their IT requirements.

To this end, construction work commenced at DML at the end of March on the new purpose-built computer facility (Fig. 31) that will house the systems.

K Sinclair (SAMS/UHIp),
J Watson, K Smalley and G Ryan (CCMS-DML)

Marine Biodiversity

Dr Mike Burrows

Measurement, maintenance, modelling and consequences of change

This work, in collaboration with colleagues at the Plymouth Marine Laboratory, aims to improve our understanding of the processes that shape patterns of biological diversity at a range of different scales. From genes through individual organisms to more complex ecological systems, biodiversity is under threat from a wide range of natural and man-made hazards. There is an increasing need for guidance to help protect and encourage biodiversity at national and local levels. The programme has four main themes:
(i) measuring change in marine biodiversity at different scales by theoretical development of estimation techniques, especially for rapid assessment; (ii) determining ecological mechanisms that maintain biodiversity; (iii) the consequences of lost biodiversity for performance of individuals, populations and the functioning of marine ecosystems and (iv) modelling and prediction of biodiversity.

At DML we are investigating the role of habitat selection behaviour as a mechanism generating patterns of diversity, the effects of bioturbation on biodiversity in sediment communities, and the link between biodiversity and trophic interactions.

Effects of bioturbation on biodiversity in sediment communities

Disturbance events, operating at a range of scales and frequencies, can maintain the spatial heterogeneity of marine soft sediment environments through the creation of a mosaic of patches in varying states of recovery. The effects on the community structure and diversity of infauna resulting from feeding, burrowing and locomotory activity of larger megafaunal animals is being investigated in contrasting habitats. Work at sites in Loch Creran, Argyll (Fig. 32) and Jennycliff Bay, Devon, is exploring the hypothesis that infaunal species diversity is related to the presence or absence of megafaunal surface features (mounds and openings).

Diver mapping, photography and remotely operated vehicle images are being used to determine the spatial distributions of features and these will be related to the diversity and abundance of infauna extracted from sediment cores. In addition, underwater television is being used to investigate the behaviour of megafaunal species such as the Dublin Bay prawn *Nephrops* (Fig. 33). Locomotory and foraging activity can be compared to that of other mobile epifauna and related to patterns of infaunal diversity and abundance, the latter being significantly lower in Loch Creran than at the Devon site.

Fig. 32 The sheltered upper reaches of Loch Creran provide an excellent environment for *in situ* studies. *© John Anderson, Highland Image*

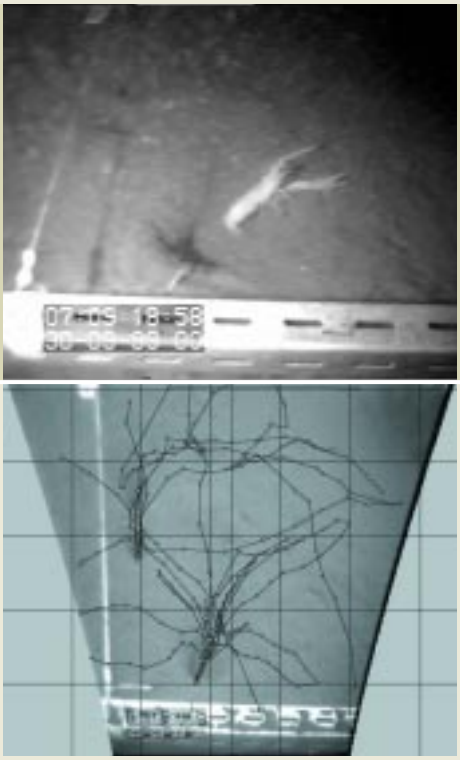


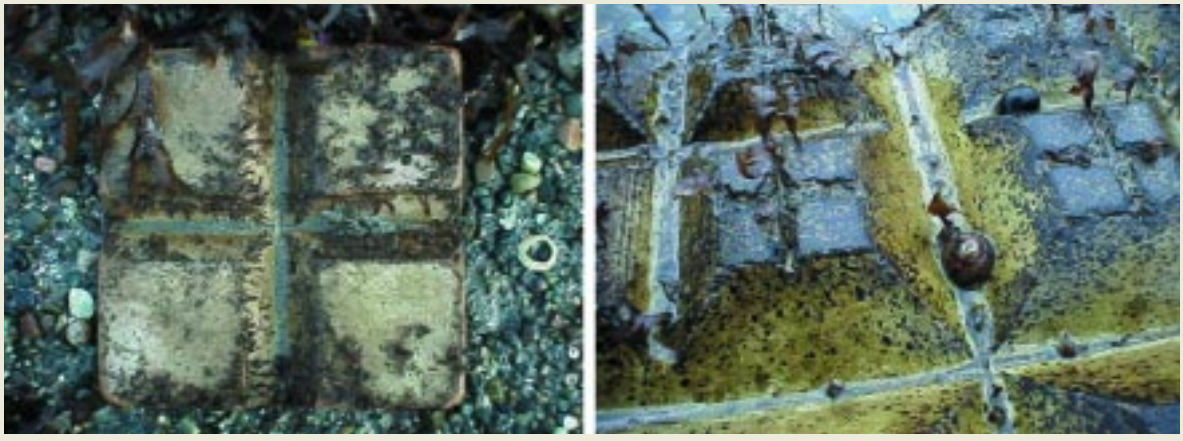
Fig. 33 Top: a *Nephrops* emerges from its burrow. Below: tracks of *Nephrops* over 24h, after correction for perspective effects, showing concentration around burrow openings.

Effects of surface topography on community development on rocky shores

Field observations suggest that surface topography plays a major role in the development of community patterns on rocky shores. To test this hypothesis, a series of concrete blocks of varying degrees of surface complexity was cast. The blocks were deployed on the lower shore for natural colonisation to occur (Fig. 34). While the study is not yet complete, important associations have emerged. At an exposed site, grazing by shore snails has been mainly confined to the artificial crevices in the block. The result is a greater colonisation of the open surfaces by algae. At a more sheltered site, where grazers are less common, grazing is less obviously confined to crevices, resulting in a denser but more evenly distributed cover of algae than at the exposed site.

MT Burrows, RS Batty, LA Nickell, RN Gibson, L Robb and R Harvey (CCMS-DML) and **N Frost** (University of Southampton)

Fig. 34 Artificial surfaces of varying complexity. After six months, algae have begun to colonise the surface of the blocks. Small *Fucus* plants appear along the outer vertices of the less complex block in sheltered conditions (left). The encrusting alga *Ralfsia* is confined to the upper facets on a more complex block at an exposed site (right), while the major surface grazers here (littorinids and topshells) are mainly in the crevices between facets.



Dr Bob Batty

Environmental cues used by migrating juvenile flatfish

Juvenile flatfish (plaice, Dover sole, dab, turbot, brill) spend their first summer on sandy beaches. All these species have been shown to migrate following the ebb and flow of the tide. Studies of plaice behaviour in light and temperature gradients have shown that both of these environmental parameters are used to direct their circatidal and circadian migration. This year, experiments on habitat selection have focused on cues used by juvenile turbot to direct their intertidal migrations. Juvenile plaice occupy the region from the shore to 5 m depth but turbot tend to be concentrated in the shallowest 0.5 m of water.

Turbot were caught locally at low water and placed in 3 m-long tanks with a horizontal gradient of either temperature (10–17°C) or light. Unlike plaice, no fish responded to the temperature gradient by selecting markedly different temperatures at different times of day. In the light gradient, however, turbot moved towards the lighter end of the tank at or before high water or to the darker end of the tank before low water (Fig. 35). Turbot also prefer higher temperatures than the migratory plaice and the non migratory dab.

These differences in behaviour are consistent with the distribution of turbot very close to the shore remaining in the warmest water at all states of the tide and times of day. Close to the shore, light gradients will be most intense but subject to considerable variability, caused by variation in cloud cover, wave action, seasonal growth of macroalgae and human activities.

Further experiments will be designed to test the effects of random changes in light intensity superimposed on a light gradient.

RS Batty (CCMS-DML)

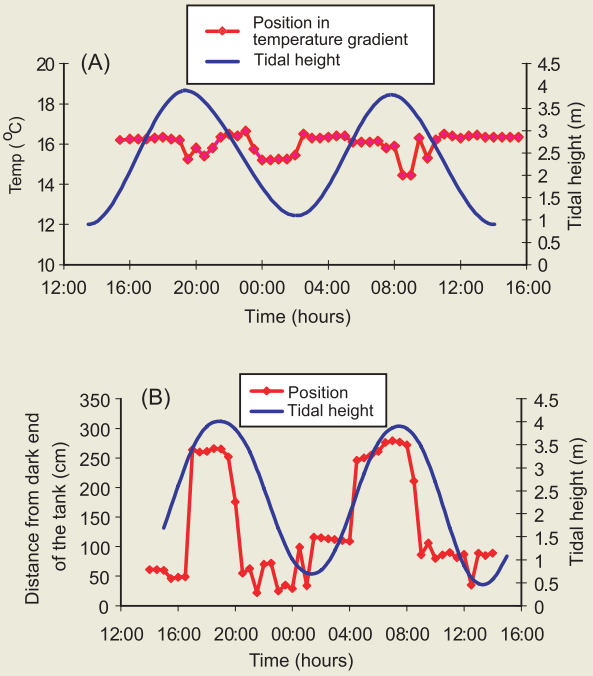


Fig. 35 Positions selected by juvenile turbot within (A) temperature and (B) light gradients.

Fish biology and environmental change

Dr Martin Sayer

The ability of marine animals to survive the critical early life history stages, grow and reproduce is continually influenced by their environment. Both natural changes and human influences can be harmful. The projects described below are all examining the effects of environmental change on fish and fisheries of commercial importance.

Environmental variation and inshore fishes

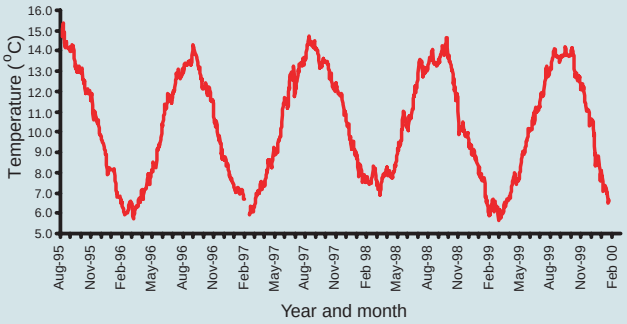
Inshore rocky subtidal environments are important for the initial post-settlement stages of the Atlantic cod *Gadus morhua* (L.). A five-year project, funded by the Ministry of Agriculture Fisheries and Food, has investigated the causal links between environmental change and year class strengths of juvenile cod and other marine animals found in that environment. One of the objectives was to establish a continuous time-series of subtidal temperature recordings in areas on the west coast of Scotland associated with juvenile gadoid settlement. These measurements have indicated tidally driven variation of up to 4°C in seawater temperatures, with freshwater run-off producing additional temperature variability. The most interesting discovery has been the occurrence of an exceptionally warm winter in 1997/1998, on average over 2°C warmer than the other 4 winters recorded (Fig. 39). There are indications that the warm winter affected the fish communities 0f the summer of 1998, with very few gadoids but significantly higher numbers of gobies and wrasse being observed.

Laboratory-based experiments have examined the effects of slight differences in temperature and/or salinity on the physiology and behaviour of juvenile cod. A behaviour assay was used to examine the effects of a range of water quality conditions on the feeding behaviour of wild-caught and hatchery-reared juvenile cod. Salinity variation alone had no significant effect on the time taken to locate a hidden food source but there were additive effects of salinity and temperature change applied together. The wild-caught juveniles displayed quicker location times than the hatchery-reared animals throughout the range of treatments.

Initial physiological results show there is little change in blood plasma osmolality or chloride concentration in response to changing temperature or salinity, indicating this species' ability to osmoregulate over a wide range of water quality conditions.

S Magill and MDJ Sayer (CCMS-DML)

Fig. 36 A 5-year subtidal seawater temperature profile obtained from submerged autonomous temperature loggers. Each value is a daily average of 120 measurements.



Fish biology and environmental change

© John Anderson, Highland Image

Fig. 37 Looking down the Firth of Lorn over the Island of Lismore. The proposed location of the artificial reef is close to the small Islet on the left.

Artificial habitat manipulation

Manipulation of the habitat in a way that optimises biological requirements for animals of commercial importance has long been proposed as a method of farming the seas. Artificial reef creation is an established fishery tool in many tropical and sub-tropical regions of the world. However, the method is largely untested in northern temperate waters. Through significant investment from the Foster Yeoman quarrying company, DML is in the position to deploy an experimental reef system off the Island of Lismore in the year 2000 (Fig. 37). The reef system will consist of twenty four units and will examine effects of two levels of block complexity, two levels of reef design complexity and a gradation of hydrological and sediment change on the communities that will develop post-deployment.

A significant proportion of the pre-deployment phase has concentrated on the collation of biological, sediment and hydrological information against which post-deployment comparisons will be made. The reef complex will be the largest artificial reef constructed for experimental purposes in the world. A series of meetings was held with local stakeholders to ensure that the project was compatible with existing fishing activities and to allay concerns regarding environmental intervention on the proposed scale. To this end, work in 1999/2000 has concentrated on complying with legislation concerning marine construction projects. One part of this work has examined the likelihood of trace metals leaching out of concrete products. Methods designed to maximise leaching, coupled with highly sensitive Inductively Coupled Plasma Mass Spectrometry measurements, failed to detect metal levels in the leachates that would influence background concentrations following deployment (Fig. 38). These and other results are being used by governmental and inter-governmental bodies charged with the implementation of EU-wide policy on large-scale marine construction projects.

Funding for this research programme has come from the EU PESCA scheme, Foster Yeoman Ltd., Argyll & the Islands Enterprise and Lochaber Enterprise. Project co-ordination was assisted through the Marine Resource Initiative.

TA Wilding and MDJ Sayer (CCMS-DML),
S Bell and J Smith (University of Aberdeen) and
J McConville (University of Edinburgh)

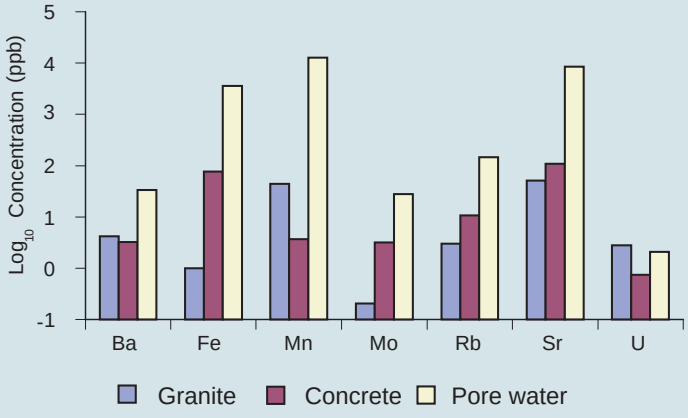


Fig. 38 A comparison of heavy metal levels derived from granite, sea loch sediment pore waters and the concrete blocks intended for deployment in the experimental artificial reef.

Fish farming: species diversification

The fish farming industry on the west coast of Scotland has long identified lack of diversification as a potential limit to future stability. This project has assessed the potential of farming lumpsuckers *Cyclopterus lumpus* (L.) in Scotland using sea cages and diet types already in use by the salmon farming industry. The project concentrated on the effects of habitat change on the ability of a non-domesticated fish to grow and survive in culture. The lumpsucker proved to be extremely resilient to changes in habitat and grew faster than farmed salmon *Salmo Salar* (L.) in cages. A lumpsucker-specific artificial diet was formulated as part of the study and a detailed economic assessment of the potential was carried out. The main product of lumpsuckers is the roe, which, when dyed, provides a low-cost alternative to caviar. The flesh is also edible and research was conducted into the use of blood products for biopharmaceutical purposes.

This successful project has shown that the lumpsucker is a promising new species for aquaculture. Trials on optimising food presentation schedules (Fig. 39) and stocking densities were also conducted during the year.

This research programme was part of the MAFF/NERC LINK Aquaculture Initiative, with additional in-kind support from BOCM PAULS fish feed group, Salar Ltd., FirstLink UK and Inverawe Fisheries. Additional funding has come from the EU PESCA scheme, Highland Council and Highland & Islands Enterprise.

S Gibson, G Thomas and MDJ Sayer (CCMS-DML) and **J McConville** (University of Edinburgh)

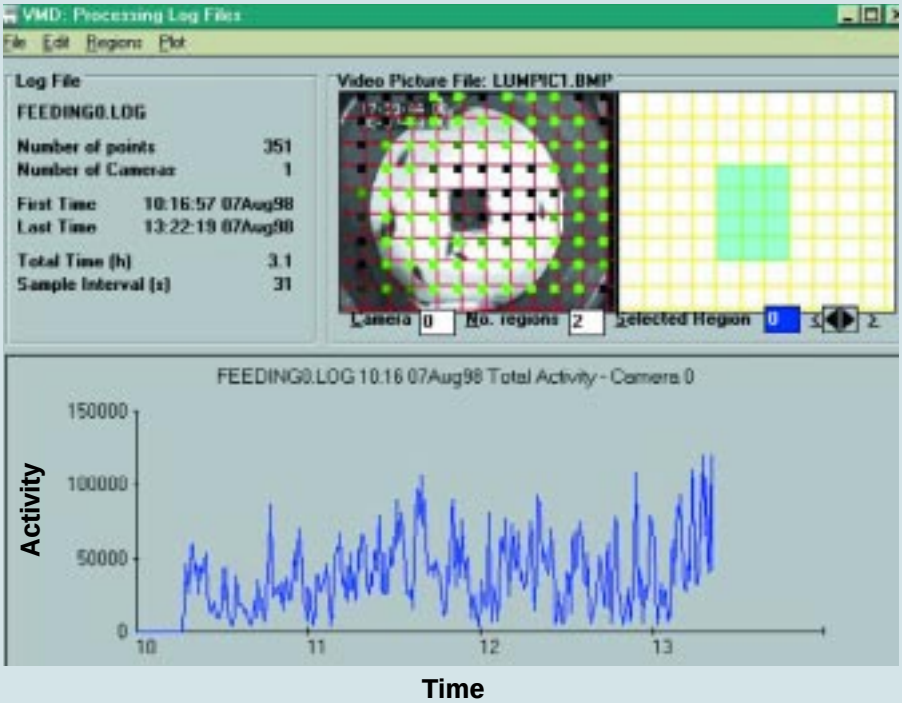


Fig. 39 Using real-time computer-generated analysis, temporal and spatial activity patterns can quickly be derived, which can optimise feed delivery in aquaculture. This example shows activity profiles for cultured lumpsuckers over a period of three hours.

Biogeochemistry

Dr Ken Jones

Restricted Exchange Environments (REEs)

The CCMS REEs programme, which began in April 1999, aims to increase our ability to predict the behaviour of UK REEs, their interactions with open waters and their vulnerability to anthropogenic perturbations and global change. The programme combines the expertise in fjordic processes at Dunstaffnage with that of the Plymouth Marine Laboratory in estuarine processes. Research projects will exploit differences in the spectrum of forcing mechanisms, determined by contrasting geomorphology, seasonality, trophic status and anthropogenic disturbance, between these UK REE types and others, to investigate their sensitivity to perturbation and ultimately derive health indices for these systems.

The relationship between input of organic matter and nutrients to the coastal zone and the development of eutrophication is of current national and international concern. Problems are frequently most acute in coastal areas where the effects of vertical mixing and horizontal exchange are reduced, either by the natural topography and hydrography (e.g. estuaries and coastal embayments), or by man-made structures (e.g. barrages, lagoons). Within a UK context, Scottish fjordic sea lochs are perhaps the most extreme examples of natural restricted exchange environments, some of which may retain water, isolated from coastal exchange, for several years. Planktonic ecosystem function and biogeochemical cycling in these environments are fundamentally different from those in other estuarine types. In the extreme, sea lochs are predisposed to increased storage of nutrient and organic inputs, making some of them particularly susceptible to eutrophication, development of algal blooms and hypoxia. One of the key challenges facing regulators and planners in these environments is the determination of critical thresholds above which catastrophic changes to biogeochemical status, biological community structure and ecosystem function occur. This is a multidisciplinary problem requiring both an understanding of how sea loch systems respond to natural forcing and knowledge of the specific effects of anthropogenic perturbation.

The principal focus of the Dunstaffnage input to the REEs programme during the year has been the study of physical and biogeochemical processes controlling the development of an intense hypoxic episode within the upper basin of Loch Etive (Fig. 40) and concomitant effect on cycling of redox sensitive metals such as manganese. Seasonal changes in hydrography, dissolved oxygen, chlorophyll and

© John Anderson, Highland Image

Fig. 40 RV *Calanus* at work in upper Loch Etive.

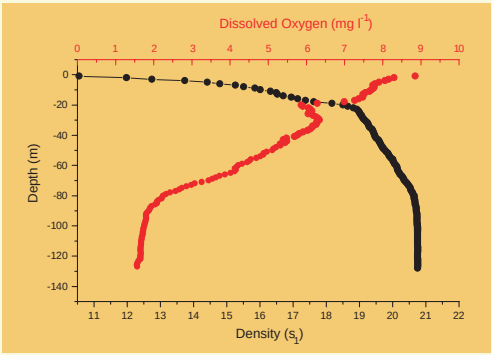


Fig. 41 Strong density stratification in the deep basin of Loch Etive in October 1999 and an oxycline from 30 to 80 m depth.

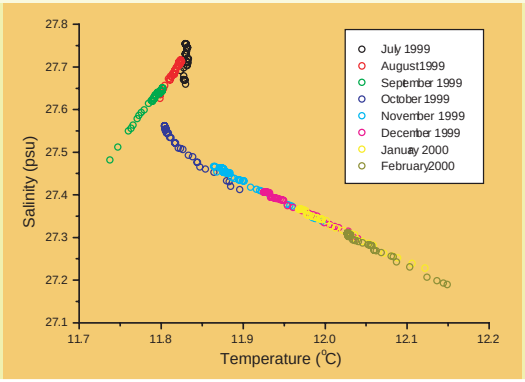


Fig. 42 Temperature and salinity changes in the deep basin of Loch Etive from July 1999 – February 2000.

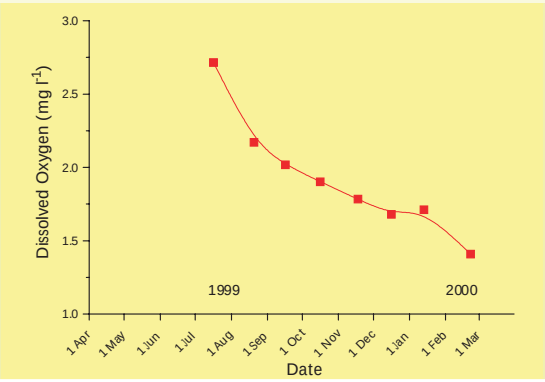


Fig. 43 Changes in oxygen concentration below 80 m depth from July 1999 – February 2000 in the deep basin, Loch Etive.

particulate distributions within the loch, together with measurements of benthic and pelagic oxygen uptake rates, have been investigated through monthly sampling. The deep water in the upper basin of Loch Etive has a maximum depth of 145 m and was isolated from exchange with surface waters by strong stratification down to sill depth (Fig. 41). Below 30 m a strong oxycline persisted from September 1999 through March 2000 and vertical stratification was maintained until May. The largely isolated deep water gained heat and lost salt during this period by diffusive mixing through the pycnocline (Fig. 42). There were no advective inputs to the deep water after August. Oxygen concentrations below 80 m fell from 2.5 mg l^{-1} in July t0 below 1.5 mg l^{-1} in February (Fig. 43), lower than recorded in previous studies. Using these data a mean oxygen utilisation rate for the deep water over the study period August-February was estimated as 97 mg O_2 m^{-2} h^{-1}. This suggested that the deepest water had been isolated for at least a year before the beginning of the present study. Using experimental oxygen uptake rates and coarse estimates of oxygen flux from our previous studies in the loch, combined with measured oxygen gradients, it has been possible to estimate an oxygen budget for the deep water which agrees with the observed rates of oxygen depletion in the basin within a factor of two. Organic remineralisation within the water column, presumably associated with suspended particles, has been shown, on average, to be 15 times greater than benthic remineralisation during the study period.

KJ Jones, IA Ezzi, SM Harvey, T Brand, J Overnell and C Griffiths (CCMS-DML)
TM Shimmield (SAMS),
M Inall (SAMS/UHIp) and
S Dixon (University of Bradford)

Processes of vertical exchange in shelf seas (PROVESS)

This is an EU MAST–funded interdisciplinary study of the vertical exchange processes in the water column and at its surface and bottom boundaries. It is based on integrated application of new methods of direct turbulence measurement, new advances in turbulence theory and new models at contrasting sites in the southern and northern North Sea. Dunstaffnage expertise in benthic microbial remineralisation processes, pelagic carbon and nutrient cycling and *in situ* chemical and biological measurements is contributing to parameterisation and testing of coupled, physical-biological models being developed by other partners.

In March and April 1999, Dunstaffnage scientists participated in two cruises on the RV *Pelagia* and RV *Mitra* to investigate these processes in the southern North Sea. *In situ* fluorometers and nutrient analysers (nitrate and silicate) were used to monitor the development of the spring bloom and associated nutrient dynamics in the shallow but highly stratified coastal waters close to the Dutch coast off Scheveningen. Process studies of benthic and pelagic nutrient and oxygen fluxes, carried out in collaboration with scientists from Centre d'Oceanologie de Marseilles, have enabled the effects of turbulence on sediment-water coupling to be evaluated.

KJ Jones, IA Ezzi, and SM Harvey (CCMS-DML) and **S Dixon** (University of Bradford)

Manganese cycling in the waters of Loch Etive

The deep waters in the upper basin of Loch Etive and Loch Fyne become hypoxic because of the continuous consumption of oxygen by microbial processes, both in the water column and sediment, coupled with poor water exchange. Manganese normally occurs in the oxidised (IV) state, but where there is severe hypoxia e.g. in sediments, it can go into solution as the (II) state. Hypoxia in the deep basin of Loch Etive leads to the release of dissolved manganese(II) from the porewater within the sediment into the bottom water overlying the sediment. Turbulent processes within the water column lead to upward diffusion of the manganese and downward diffusion of oxygen. A relatively slow reaction between the dissolved manganese(II) and oxygen produces particulate manganese(IV) which falls to the sediment to complete the cycle.

Work to quantify this cycling and to map the distributions of dissolved and particulate manganese in the water columns of Lochs Etive and Fyne has been funded by the NERC Thematic Programme 'Autosub Science Missions'. The Autosub deployment to sample the water column and to measure the dissolved manganese was completed in March 2000. Complementary time-series measurements of dissolved and particulate manganese and iron, along with dissolved oxygen, were obtained in Loch Etive by traditional water sampling.

The manganese data (Fig. 44) show a high concentration of both forms of manganese near the bottom and this roughly corresponds to a low oxygen concentration.

J Overnell, KD Black and T Brand (CCMS-DML) and **PJ Statham** (Southampton Oceanography Centre)

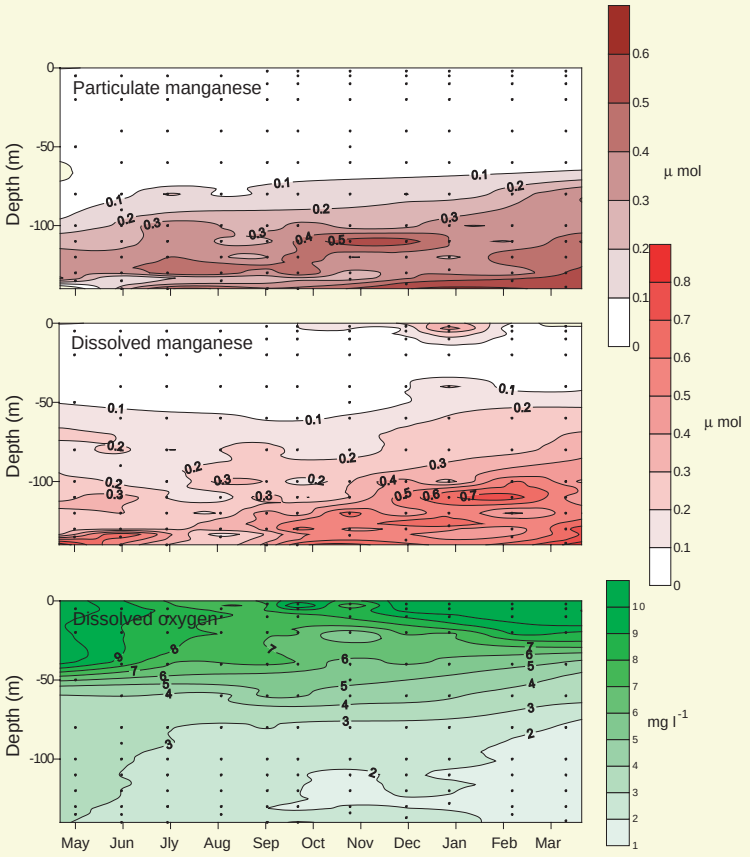


Fig. 44 Contour plots of particulate and dissolved manganese and of dissolved oxygen versus depth as a function of time at the deep station in the upper basin of Loch Etive (140 m). The dots mark the positions of the individual samples.

Dr Kenny Black

An applied model for predicting the fate of particulate discharges from mariculture

Increasingly, both government regulators and fish farmers find themselves seeking better predictive capability coupled with objectivity in determining the environmental conditions at existing and proposed sites for salmonid cage culture. With this information, efforts can be concentrated on sites which are likely to have good husbandry characteristics or have good potential for expansion, thus minimising the costs of future monitoring of impact on the sea bed. This project aims to provide an agreed predictive tool for both the regulator and the industry and is funded under the NERC LINK Aquaculture Programme.

The deposition model DEPOMOD, which runs on a Windows 95™ platform, features grid generation, particle tracking, resuspension and benthic response characteristics. A sub-model is also available for predicting feed input throughout a growing cycle as this directly affects wastage rates. In order to validate DEPOMOD, sediment trap studies were conducted to investigate the initial deposition of material from a dispersive and a depositional fish farm. Model predictions achieved an accuracy of ±20% and ±13% respectively. A field trial and modelling study were then undertaken to assess the resuspension of a particulate tracer from the sea bed, an aspect which has been neglected in similar models. Total mass budgets were predicted within ±7% of total tracer released. The benthic response model was then developed to establish semi–empirical relationships between predicted accumulation of solids and benthic indices measured at numerous fish farms.

DEPOMOD can be used for prediction of solids flux (g m^{-2} seabed yr^{-1}) of waste food and faecal material and associated impacts from an operational farm at any stage of the growing cycle. Prediction of the total deposition and sediment concentration (g kg^{-1} sediment) of the active ingredient of in-feed sea lice treatment chemicals has also been undertaken using DEPOMOD. An additional version of DEPOMOD is being developed to model the behaviour of sea lice treatment chemicals.

CJ Cromey, TD Nickell and KD Black
(CCMS-DML), in collaboration with Marine Harvest McConnell, Scottish Environment Protection Agency, Scottish Environmental Advisory Services and the Scottish Salmon Growers Association

Coastal Impact Research Group

© David T Meldrum, DML

Fig. 45 DGPS base station installed close to a salmonid cage unit.

Use of differential global positioning system (DGPS) drifter buoys for measurement of dispersion in Scottish sea loch systems

Models for determining discharge consent levels to sea loch systems from fish farms and long sea outfalls are in common use by regulatory bodies in the UK and Europe. These include advection–diffusion and particle tracking models. Currently, standard diffusion coefficients are applied across all sea lochs in the absence of site-specific measurements. Such methods are inappropriate in sea loch basins, which exhibit varying degrees of restricted exchange, especially as models show some sensitivity to horizontal and vertical diffusion coefficients. Dye methods are commonly used by dischargers in studies on the major coastal outfalls, but the presence of commercial aquaculture activities in sea lochs renders this method unsuitable. The application of differential DGPS drifter buoys (described in detail on p.49) to assess dispersion in these lochs offers a novel approach.

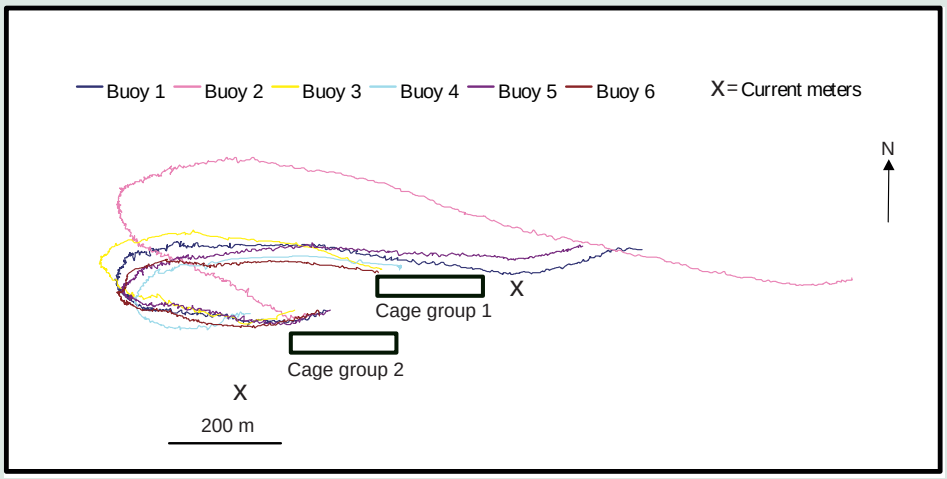


Fig. 46 Drifter buoy survey on 6 March in Loch Sunart, with positions of current meters and cage groups. Release started at 11:45, tide turned at 13:30, release ended at 15:45.

Deployments were conducted in one sea loch (Fig. 45) to assess the dispersion of a sea lice treatment chemical discharge from a fish farm (Fig. 46) and to allow calculation of diffusion coefficients for this release. Several features of the loch system considered important for determining the fate of the discharge were revealed and the data will be used in modelling studies in a new project to determine the wider effects of sea-lice treatment agents. The buoys have considerable potential for determining the dispersion characteristics of any enclosed or semi-enclosed water body, with applications in research and statutory regulation.

CJ Cromey, KD Black and DJL Mercer (CCMS-DML) and **PA Gillibrand** (Fisheries Research Services, Aberdeen)

The effects of fish farming on a micro-pelagic assemblage

Although the effects of salmonid cage-culture effluents (metabolic waste products and uneaten food) on benthic communities are now well documented, little attention has been given to the effects of such organic enrichment on planktonic community structure and microplankton ecosystem function in sea lochs. Therefore, a programme of field observations was undertaken over a complete seasonal cycle in Loch Fyne, an intensively farmed sea loch. Salinity/temperature profiles and water samples (Fig. 47) were collected from three depths at each of four stations located at different proximities to the fish farm. The water samples were analysed for inorganic (ammonium, nitrate, phosphate, silicate) and organic nutrients (nitrogen, phosphorus), chlorophyll concentrations and the abundance and biomass of bacteria, ciliate protozoans and nanoflagellates.

Preliminary results reveal higher concentrations of ammonia and organic nitrogen at the stations near the fish farm during most months. They also show higher abundance of bacteria, nanoflagellates and ciliates. The associated higher abundances of heterotrophic micro-organisms near the fish farm suggest that these nutrients may in turn be directly or indirectly enhancing microbial activity. This would seem likely as bacteria are major consumers of dissolved organic matter and are then themselves consumed by protozoans. These data have contributed significantly to our understanding of the many effects of aquaculture on semi-enclosed environments and will be used to develop models of sea loch ecosystem dynamics.

N Navarro (EU Marie Curie Fellow), **N Monerris, S Marin, KJ Jones and KD Black** (CCMS-DML) and **RJ Leakey** (SAMS)

Fig. 47 EU scholar Sora Marin processing water samples in the laboratory on board RV *Calanus*.
© Ray Leakey, SAMS

Isolated deep-water sites on the Scottish shelf

We are interested in the fate of material transported onto the western Scottish shelf from the Irish Sea, the mainland and the oceans. Attention has focused on sites up to 300 m deep west of the Inner Hebrides which are periodically isolated from the general circulation. Investigations are underway into how these accumulate organic matter and contaminants of human origin, such as radionuclides, transported in the Scottish coastal current. Among other things, these areas may shed light on recent biogeochemical recycling processes and environmental changes since the last ice age.

KD Black, CR Griffiths, SM Harvey, IA Ezzi, J Overnell and J Watson (CCMS-DML) and **TM Shimmield** (SAMS)

Marine Technology

Mr David Meldrum

The Technology Development group develops new tools and techniques that are needed to keep our science at the leading edge. A key element in our approach is the cost-effective adaptation for marine science of technologies originally developed for the military and consumer markets. Technology customers, such as the aquaculture industry and Defence Evaluation and Research Agency (DERA), participate in our developments through contracts and collaborative agreements. Particular areas of expertise, some of which are described in more detail below, include satellite-tracked drifters, satellite telemetry and control, smart instruments, sea-bed lander packages and applications utilising the Global Positioning System (GPS).

Antarctic ice buoys

As a contribution to the NERC Land-Ocean Interaction Study (LOIS) in the mid-1990s, the group developed and built a number of free-drifting satellite-tracked buoys, which yielded important new data on the exchanges between oceanic and shelf waters to the west of the Hebrides. In the interest of innovation and curiosity, a small number of these drifters were also equipped with GPS receivers. The GPS data were successfully transmitted ashore, resulting in an order of magnitude improvement in drift track definition. These new GPS techniques were then applied successfully to the tracking of ice floes in the Odden region of the Greenland Sea as part of the European Subpolar Ocean Programme (Figs 48 & 49). In collaboration with the Scott Polar Research Institute of the University of Cambridge, the Group has now been awarded a NERC research grant to build and deploy six new GPS-equipped drifters in the Weddell Sea area of the Antarctic. The buoys are equipped with a variety of sensors to monitor sea ice formation and dynamics, and were released from RV *Polarstern* in April 2000, at the onset of the austral winter. Through an important partnership with the Meteorological Office, the buoys will also transmit weather data for global forecasting.

DT Meldrum, OC Peppe and **D Mercer** (CCMS-DML)

Fig. 48 Close-up of ice drifter with stainless steel casing to resist ice abrasion.

Fig. 49 Ice drifter deployed in the Greenland Sea.

Photos © Oli C Peppe, DML

Mini drifters

GPS-equipped drifters can also be utilised in studying small-scale processes that occur in sea lochs and estuaries (see Fig. 46). For these studies the 100 metre accuracy of civil GPS is insufficient and differential techniques (DGPS) have to be used to eliminate the errors in the GPS fixes. We have built a number of small DGPS-capable drifters (Fig. 50), consisting of a cylindrical hull and antenna mast attached to a 'holey sock' drogue. The hull contains a rechargeable battery, a GPS receiver and a UHF radio link module. A base station at a known location on shore (see Fig. 45) computes the DGPS corrections, which are then transmitted to the drifters via the radio link. The drifter GPS receiver uses these corrections to perform a position calculation with an accuracy of 4 m, which is then transmitted ashore every 30 seconds for logging and display.

DT Meldrum, D Mercer and OC Peppe (CCMS-DML)

Fig. 50 Drogue and two mini drifters (one dismantled) at Dunstaffnage. *© David Meldrum, DML*

Marine Technology

© J Murray Roberts, SAMS

Fig. 51 DML lander being deployed adjacent to the Beryl Alpha production platform

Benthic landers

The group's involvement in seabed lander development and operation continued when two landers based at DML were used to aid the study of offshore drill cuttings piles in the North Sea (Fig. 51). The work, jointly sponsored by the UK Offshore Operators Association and the NERC Managing Impacts in the Marine Environment initiative, took place during a cruise on a survey vessel in the Beryl field. The landers were positioned on the drill cuttings piles between 60 m and 300 m from the platform, using the vessel's remotely operated vehicle (ROV). Deployment from the lander of a micro-electrode profiling unit developed by Unisense, Denmark, enabled the first *in situ* measurements of oxygen and sulphide profiles in such conditions to be obtained (see p. 8 for more details). The high resolution profiles (50 µm) showed a very rapid decrease in oxygen, and subsequent increase in sulphide, below the surface of the cuttings piles. The second lander was fitted with a gel-peeper module developed at the University of Lancaster, giving *in situ* measurements of metals concentrations. The use of two landers maximised the results obtained from a very short cruise, and ensured a minimum of disruption to the vessel's ongoing survey work.

D Mercer, OC Peppe, J Watson and E Breuer (CCMS-DML)

AutoMERS and the new lander centre

In collaboration with the Universities of Aberdeen, St Andrews and Bristol, the Laboratory has been successful in winning support from the Joint Infrastructure Fund (JIF) for a major investment in lander development. The programme, called Autonomous Marine Environmental Research Stations (AutoMERS), will involve the building and equipping of new facilities for lander storage and maintenance at DML, as well as improvements to the pontoon access. A substantial investment in both lander equipment and instrumentation also forms part of the grant. This, together with access to the major test and development facilities being built at Aberdeen, will greatly enhance our capability for supporting lander operations and continuing the development of lander instrumentation. DML will also become the in-shore test base for AutoMERS, making use of the RVs *Calanus* and *Seol Mara* and nearby sheltered deep water sites.

DT Meldrum, OC Peppe, D Mercer and KJ Jones (CCMS-DML), **GB Shimmield and JD Gage** (SAMS)

Internal wave studies

The group continues to provide technology, instrumentation and navigation support to a team from DERA Farnborough studying the radar imaging of naturally generated internal waves in the Mediterranean and elsewhere. This year members of the group have also made significant contributions to the analysis and interpretation of data collected during these trials.

DT Meldrum, C Griffiths, D Mercer and OC Peppe (CCMS-DML) and **M Inall** (SAMS/UHIp)

Culture Collection of Algae and Protozoa

Dr Christopher Bolch

Algae for research, industry and biotechnology

The Culture Collection of Algae and Protozoa (CCAP) is the major UK collection of marine algal diversity, currently holding approximately 600 strains from more than 15 classes of marine algae and protozoa. These groups encompass many of the most genetically and biochemically diverse taxa on earth which are of potential commercial value for lipids and fatty acids, pigments and antioxidants, pharmaceutical or health products, or other biologically active molecules. It is clear from what is already known about their biochemistry that they harbour a wealth of novel compounds and associated biochemical systems. The CCAP collection includes many commercially important species used in aquaculture and industry, a range of rare or endangered red algae of national significance and many species of potential value as a resource for marine biotechnology and commercial exploitation.

CCAP is associated with the UK National Culture Collection (UKNCC) and the strain database is now accessible via the UKNCC database website (http://www.ukncc.co.uk). An updated CCAP catalogue is also due for release during 2000. CCAP supplies more than 600 algal starter cultures per year to academic research institutions, such as Universities and other public research bodies, and a range of commercial customers, such as ecotoxicity testing laboratories, biotechnology companies and aquaculture industries around the world. The Collection's customer base and income from sales continue to grow with the bulk of sales being to customers based in the UK and other EU countries.

The past year was one of change for CCAP. Following the retirement of Michael Turner in 1998, Christine Campbell successfully steered the Collection through to the appointment and subsequent arrival of Dr Christopher Bolch as Head of CCAP in August 1999. With this appointment, a new direction has been set: to expand CCAP's research activities while maintaining its function as the national resource collection for marine algae and cyanobacteria. The expansion has been facilitated by CCMS funding of a new £50K molecular genetics laboratory to undertake strategic research on marine algal phylogeny, systematics, population genetics and harmful algal blooms. Molecular studies of spatial and temporal diversity in other marine organisms are also accommodated in the new facility.

CJS Bolch, CN Campbell, P Proudlock and J Cocker (CCMS-DML)

CCAP research

CCAP research activities focus on marine planktonic micro-algae and protozoa, but the techniques and population genetic concepts are relevant and applicable to examining spatial and temporal diversity in other marine organisms. Such studies are accommodated in the CCAP molecular genetics facility.

Culture Collection of Algae and Protozoa

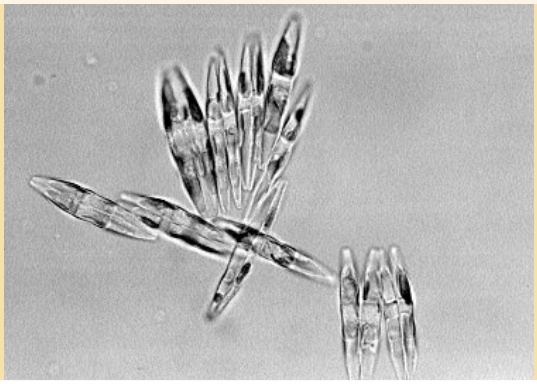


Fig. 52 The toxic diatom *Pseudo-nitzschia australis*

Genetic diversity and spatial variation in marine organisms

Marine planktonic organisms live in an ever-changing, heterogeneous, three dimensional environment and evidence suggests that speciation and dispersal mechanisms in these organisms differ markedly from those on land. CCAP is therefore addressing the following issues:

- The spatial structure and scale of marine genetic diversity and how it differs in contrasting marine environments (e.g. neritic vs. oceanic, eutrophic vs. oligotrophic or benthic vs. planktonic
- Different reproductive strategies or ploidy levels and how they contribute to genetic diversity of the ecosystem
- The comparative resistance to invasion of genetically diverse communities and the effect of ecological disturbance

These questions can be tackled using recently developed molecular techniques (e.g. nucleic acid or protein sequences and DNA fingerprinting methods), thereby aiding the identification of taxonomically difficult groups, monitoring and assessing rapidly fluctuating mixed populations, or assessing short- and long-term changes in population diversity. Molecular approaches are particularly valuable in microscopic organisms where traditional biological approaches are not logistically possible on relevant time or spatial scales.

Bloom dynamics and population genetics of toxic micro-algae

The spatial structure of genetic diversity of a species results from a combination of their reproductive biology and its interaction with environmental and physical factors which structure the ecosystem. Until recently it was assumed that marine organisms with predominantly clonal reproduction and high dispersal capacities would be genetically homogeneous and not show geographic structure and relationships. The application of molecular methods, however, has now shown that this is not the case i.e. the concept of a temporally stable, globally distributed species is no longer valid. Recent studies now indicate surprisingly small-scale population structuring in algal bloom populations and that temporal genetic change can often be greater than spatial change or change between species. Rates of genetic change can occur on ecologically relevant time scales and may play a role in determining how local adaptation and speciation can occur in apparently homogeneous populations.

During the current year, research activities focused on amnesic shellfish poisoning (ASP) contamination in western Scotland's king scallops *Pecten maximus*. In collaboration with Dr Maeve Kelly (SAMS), who is examining variation of ASP toxins in scallops and depuration of ASP toxins (see p. 19), CCAP has been identifying the causative organisms - diatoms of the genus *Pseudo-nitzschia* (Fig.52). These studies have identified no less than seven potentially toxic species, dominated by the known toxic species *P. australis* and *P. pungens*, which are now being grown in culture at DML to determine their ability to produce ASP toxins.

CJS Bolch, CN Campbell and P Proudlock (CCMS-DML),
MS Kelly and DA Campbell (SAMS)

Inside the Laboratory's hyperbaric chamber

Diving and small boats

The diving and small boat section supports a number of research programmes both in-house and in collaboration with other scientific institutes, including Millport Marine Station, University of Stirling, University of Aberdeen, Heriot-Watt University, Southampton Oceanography Centre, British Antarctic Survey and Plymouth Marine Laboratory.

The eight-strong scientific team is supported by two full-time dive technicians, all of whom are skilled in a broad range of disciplines related to scientific diving. It is our policy to offer continuing training to team members, in order to maintain the highest standards and develop new skills. We also offer training to other organisations in: safe use of Nitrox (oxygen-enriched air) in accordance with Health and Safety Executive guidance, Marine VHF radio, Royal Yachting Association power boat level 2, Recompression Chamber familiarisation and the safe use of semi closed-circuit re-breathers.

Our development programme includes photographic/video survey and 'no clear surface' techniques in addition to full face mask combined with 'hard wire' in-water communications (between diver and supervisor). This will ensure that DML divers are at the forefront of diving techniques.

Within the diving facility is a well equipped two-metre diameter recompression chamber, complete with patient monitoring system. This hyperbaric unit offers emergency diver treatment 365 days of the year and is the busiest diver treatment facility in Scotland, having treated 17, mainly recreational, divers during the year. It is our intention to upgrade the facility to incorporate Heliox gas treatment in response to more complicated cases of decompression illness brought about by advances in technical diving and the wider use of mixed-gas diving in the sports diving sector.

The expertise and experience contained within the Laboratory's diving unit is increasingly called upon to advise and support scientific diving both in UK waters and abroad. Members of the dive team advise the Health and Safety Executive Diving Industry Committee, the Scientific Diving Supervisory Committee and the Society for Underwater Technology Diving and Manned Submersible Committee, thus contributing to legislation governing diving for scientific and archaeological purposes.

In the last year, 277 dives were conducted, mainly in support of commissioned research and included: site surveys, species recording, sediment coring, specimen collection, video recording/stills photography and various diver-assisted deployments and recoveries of scientific equipment.

R Wood and S Thurston (CCMS-DML)

Scientific Services

Aquarium

The Laboratory's aquarium comprises the main aquarium and annexe, seven air-conditioned and constant temperature rooms, and separate indoor and outdoor aquaria for the biotechnology building.

This year has seen further upgrading of the facilities, funded by a NERC Eco Loan. All five air-conditioned rooms now have new air-conditioning and temperature control units which are more energy-efficient and accurate. Six independently heated one-metre tanks have been installed in the main aquarium as part of a 16-tank experimental system which facilitates research on growth and development under a range of temperature regimes. At present, this system is hosting work on growth and development of king scallops.

Work has continued on improvements to the quality of seawater supplied to the site. The seawater in the biotechnology building is now drawn through new sub-sand intakes and the main building aquarium facilities will be connected to this system in the coming year. The existing system of reservoir tanks and solenoid valves, allowing recirculation of seawater at extreme low tides, will be retained.

Over the past year, the aquarium facilities have accommodated work on fish physiology, deep-sea corals, animal-environment interactions, invertebrate biology and mariculture, and growth and development of cephalopods.

A Keay (CCMS-DML)

© John Anderson, Highland Image

The aquarium annexe set up for herring culture.

RV *Calanus* leaving Loch Etive

Research vessels

The Laboratory continues to operate two research vessels, RV *Calanus* and RV *Seòl Mara*, with state-of-the-art navigation and marine sampling equipment.

At the beginning of the year, a new electric/hydraulic winch was purchased which is fitted with a 500-metre fibre/electric armoured cable, giving scientists the ability to deploy a large number of sophisticated electronic instruments. It has been primarily used during the year to tow a multiple opening/closing net system (MOCNESS).

The vessels play an essential part in the science and teaching programmes carried out by SAMS, DML, CCMS and the UHIp. Other organisations which have made use of the vessels in the current year have included the Universities of Stirling, Strathclyde, Edinburgh, Southampton Oceanography Centre (Autosub), Defence Evaluation and Research Agency, Ultra Electronics and the Lochaber Fisheries Trust.

A comprehensive deep side-scan survey of Loch Etive was carried out by Ultra Electronics using RV *Calanus*. This has provided DML scientists with a high quality chart of the bottom topography, the previous chart being over 100 years old. RV *Calanus* also made her first venture out of Scottish waters when she was chartered by the British Geological Survey to carry out a coring survey in the Irish Sea off Sellafield.

Customer	**RV *Calanus***	**RV *Seòl Mara***
DML/SAMS/CCMS/UHIp	138	183
Southampton Oceanography Centre (Autosub)	42	0
British Geological Survey	9	0
Lochaber Fisheries Trust	7	0
Ultra Electronics	6	0
Scottish Universities	2	4
Refit, maintenance and lie up	47	58
Total days	251	245

J Watson (CCMS-DML)

Library

The joint library of SAMS and CCMS-DML was again heavily used by staff, students, members and visitors. The Library's shorter catalogue, journals list and publications database are all available via the Local Area Network within the Laboratory, as are the current awareness bulletins kindly provided by the National Marine Biological Library at the Plymouth Marine Laboratory.

Publications and reports from institutes world-wide are received via the Exchange Programme, and the Library has also benefited from generous donations of books from other institutes and individuals. SAMS continues to provide a grant for book purchases.

E Walton (CCMS-DML)

Obituary

Alan D Ansell, BSc, PhD, DSc, CBiol, FIBiol

Alan Ansell began his scientific career after graduating in zoology from the University of Reading in 1956. He was awarded his PhD from the University of Glasgow in 1959 for studies on marine molluscs under the supervision of Professor (later Sir) CM Yonge. Much of this work was carried out at the Millport Laboratory on the Clyde, the former home of SMBA (Scottish Marine Biological Association - now SAMS).

After a year as an Assistant Lecturer at Glasgow, he went to the United States to study the hatchery rearing of bivalves. He then became a Central Electricity Generating Board Research Fellow of the University of Southampton. Returning to Scotland in 1964 as a member of staff at the SMBA, he began a series of comparative studies on the behaviour of bivalves concentrating on a description and analysis of movement. Research on biochemical aspects of these behaviours was followed by research examining the growth and biochemical cycle of the dominant bivalve species on Scottish sandy beaches.

In 1968, Alan spent three months in India studying the ecology of tropical sandy beaches and the following year he moved to DML where he continued his extensive biochemical studies of bivalve species in temperate waters. These lasted for several years, providing the basis for comparative work in other regions and leading to collaboration with several colleagues in France and Algeria. In 1976, he began an EC funded project in collaboration with the Station Marine d'Endoume, Marseilles, looking at the effects of temperature on marine benthos.

He was particularly interested in the bivalve mollusc *Donax* and this continued throughout his life. Following his review of the genus in 1983, he became recognised as the world authority. In 1981 he was awarded a DSc by the University of Glasgow for his ecological and behavioural studies of marine bivalve molluscs.

The mid 1980s saw his direction change as he began examining sandy beach fishes and crustaceans and their influence on bivalve populations, especially on *Donax*. In addition to molluscan biology, he was also involved in collaborative studies on the crawfish *Palinurus*, the urchin *Echinus* and brachiopods. Latterly he had a major consultatory role in a project designed to examine the bioturbatory effects of the echiuran *Maxmuelleria* on the distribution of radionuclides on the sea bed.

He retired in 1994 but continued to work at Dunstaffnage as a SAMS Honorary Research Fellow. While writing up some of his past work, he could not resist the temptation to start new projects including a return to one of his former interests - the locomotory behaviour of bivalves, this time involving Antarctic species.

Alan was a great traveller and visited most parts of the world either to attend conferences or to undertake research. He also enjoyed teaching, for a time being an Honorary Lecturer at the University of Stirling. He was a member of the Marine Biological Association of the United Kingdom, the Malacological Society, the Challenger Society and a Fellow of the Institute of Biology.

Alan combined a highly successful life at work with many activities in the local community. He was a member of the Speakers Club and one of the leading figures in the Oban Flower Club, being invited to judge at events in the area. He was a generous man who always gave freely of his time and knowledge. A family man devoted to his wife, two children and four grandchildren, he is sadly missed by his friends and colleagues at Dunstaffnage and around the world.

Other Laboratory Activities

© John Anderson, Highland Image

Professor Graham Shimmield, Director of SAMS and DML (left), welcomes many visitors to the Laboratory including Mrs Ray Michie, Member of Parliament (MP), Mr George Lyon, Member of the Scottish Parliament (MSP), and Scottish Fisheries Minister, John Home Robertson MP, MSP (right), photographed beside the Recompression Chamber at Dunstaffnage.

People of many nationalities and sections of society participate in our activities as we endeavour to promote and expand the understanding of marine science.

Primary and senior schools visited the Laboratory over four days in June and participated in imaginative demonstrations. Staff and students volunteer for this work and their enthusiasm ensures its success and vitality.

The Scottish Marine Group's twice-yearly meetings have progressed under the stewardship of Dr Hamish Mair, Heriot-Watt University. Hazel Lindsay, Napier University, won the SAMS Prize of £100 for the best postgraduate presentation at the May meeting held in Heriot-Watt University. The October meeting at the University of Stirling was exceptionally successful. UK authorities on various aspects of marine science gave presentations on progress in their disciplines during the last millennium.

Over 500 school children took part in the Argyll and Bute Regional Environmental Education Forum, Environment Fair, on 24/25 September in Campbeltown, which included a procession through the town. Liz Cook and her papier-maché sea urchin Spikey guaranteed a high profile for SAMS and marine science.

The British Association's Annual Festival of Science was held in Sheffield in September. Once again, Liz Cook and Spikey stole the show. Liz gave the Frontiers of Science Lecture (Pupil Research Initiative Conferences) to audiences of between 150-300 pupils (ages 15-17) at the Edinburgh International Convention Centre and Aberdeen University. Liz was partly sponsored by Shell Education Service.

SAMS hosted a successful international conference on symbiosis in September. Forty-four Oban High School pupils attended a special presentation by two of the speakers, the renowned scientists Professor Lynn Margulis and Professor Jan Sapp.

Two SAMS students, Bhavani Narayanaswamy and Steve Craig, organised the Young Scientists Conference *New Directions in Marine Science* at the Laboratory, which was attended by 50 students. The buzz resonating through the corridors bode well for the future.

In September, the Laboratory hosted the first workshop on marine habitat classification organised by OSPAR/ICES/EEA (Oslo Paris Convention for the protection of the marine environment of the north Atlantic/International Council for the Exploration of the Sea/European Environment Agency). Delegates from 15 countries attended and considerable progress was made on a European Nature Information System classification which includes deep water habitats. A marine habitat mapping sub-group was also established.

In November, Professor John Harwood of the NERC Sea Mammal Research Unit, University of St Andrews, gave an excellent Newth Lecture entitled *Marine mammals in the 21st century: will habitat loss be a problem?*

In December, 54 SAMS Members returned a questionnaire in which they rated SAMS activities in order of priority as follows: Newsletter, Annual Report, Scientific Meetings, Scottish Marine Group, Education Programme, Access to Library, Bursaries/Grants, Access to Laboratory, Fellowships. Council is grateful to them for the time and trouble they took to complete this and is considering their views.

During National Science Week in March, an open evening for the public was held at the Laboratory.

Helen Anderson (SAMS)

Secretary's Report

Secretary's report for the year ended 31 March 2000

The 85th Annual General Meeting of the Association was held on 1 November 1999 at the University of St Andrews by kind permission of the Principal, Professor Struther Arnott. Dr Ian Graham-Bryce was elected SAMS President with effect from 1 August 2000 and Sir David Smith agreed to continue as Acting President until 31 July 2000. Professor Sir Frederick Holliday, Sir Cyril Lucas, Professor AD McIntyre, Dr JH Steele, Professor Sir William Stewart and Professor SA Thorpe were elected as Vice-Presidents for a period of one year. Professors GA Codd and MJ Cowling retired from Council and were warmly thanked for their extremely valuable contributions to SAMS. Professor MS Baxter and Mrs M Crawford were elected to Council for a period of three years. Messrs Moores Rowland had merged with Scott-Moncrieff and changed their name to Scott-Moncrieff. Messrs Scott-Moncrieff were appointed auditors to the Association. The AGM was immediately followed by the Tenth Newth Memorial Lecture given by Professor John Harwood of NERC Sea Mammal Research Unit, University of St Andrews, on *Marine mammals in the 21st Century: will habitat loss be a problem?* In December, Professor MS Baxter tendered his resignation from Council.

The Board of SAMS met at The University of St Andrews on 1 November 1999 to discuss SAMS strategy for the next five years.

Four meetings of Council were held in the course of the year: on 1 June 1999 at Dunstaffnage following the staff review on the previous day, 10 September 1999 at Perth College, 1 November 1999 at the University of St Andrews and 18 February 2000 at the the Moredun International Research Centre, Edinburgh.

Council was served by the Finance and General Purposes Committee and the Research and Strategy Committee (formerly the Fellowship and Bursaries Committee) in their particular areas of responsibility.

The NERC SAMS Agreement is still under discussion.

G B Shimmield, Secretary, SAMS

Membership of the Association

Membership of SAMS at 31 August 2000 was 470, comprising 365 ordinary, 74 student, 30 corporate and one Honorary Member, Mr. David Ellett.

SAMS Research Bursaries awarded during the year

T H Birkbeck
■ University of Glasgow
Invertebrate hosts of the fish pathogen *Piscirickettsia salmonis*
£950

C Parsons
■ Hebridean Whale & Dolphin Trust, Tobermory
Review of cetacean ecology and biology in the Hebrides
£450

M Huxham
■ Napier University
Models of succession in soft-bottom intertidal communities
£980

T Jarvis
■ UHIp
Flux of carbon and nitrogen associated with vertical migration of zooplankton
£1000

A E J Miller
■ SAMS
Bloom dynamics of dissolved Organic Matter in Scottish Waters East of the Shetlands
£750

Statement of Accounts

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

Scottish Charity Number: SC 009206

REPORT AND ACCOUNTS

Year ended 31 March 2000

THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE

COUNCIL REPORT

Directors (styled Members of Council)

Sir David C Smith (President)
Professor G S Boulton
Professor P R Boyle
Professor GA Codd
Professor MJ Cowling
Mrs M M Crawford
Dr C D Todd

Association Director

Professor G B Shimmield

Secretary and registered office

Professor G B Shimmield
P O Box 3, Oban, Argyll, PA34 4AD

The Council submit their report and accounts for the year ended 31 March 2000.

1. Responsibilities of the Members of Council

Company law requires the Members of Council to prepare accounts that give a true and fair view of the state of affairs of the Association and of the surplus or deficit for its financial year. In doing so the Members of Council are required to:

- select suitable accounting policies and apply them consistently
- make judgements and estimates that are reasonable and prudent
- prepare the accounts on the going concern basis unless it is inappropriate to presume that the Association will continue in business.

The Members of Council are responsible for maintaining proper accounting records that disclose with reasonable accuracy at any time the financial position of the Association and to enable them to ensure that the accounts comply with the Companies Act 1985. They are also responsible for safeguarding the assets of the Association and hence for taking reasonable steps for the prevention and detection of fraud and other irregularities.

2. Principal activity

The principal object of the Association is to promote the study of Marine Science through research and education.

3. Results

The Association's results for the year were as follows:

	£
Surplus for year	7,953
Surplus brought forward	140,695
Surplus carried forward	148,648

4. Members of Council

Professors GA Codd and MJ Cowling retired at the Annual General Meeting, November 1999 and Mrs MM Crawford was elected to Council. All other Members of Council served throughout the year.

5. Auditors

A resolution to re-appoint Scott-Moncrieff Chartered Accountants as auditors will be put to the members at the Annual General Meeting.

By order of the Members of the Council

PROFESSOR GB SHIMMIELD

Secretary

1 October 2000

Statement of Accounts

Auditors Report

To the Members of The Scottish Association for Marine Science
(a company limited by Guarantee).

We have audited the accounts on pages 61 to 65.

Respective responsibilities of Members of Council and auditors:

As described in the Council report the Members of Council are responsible for the preparation of accounts. It is our responsibility as auditors to form an independent opinion, based on our audit, on those accounts and to report our opinion to you.

Basis of opinion

We conducted our audit in accordance with Auditing Standards issued by the Auditing Practices Board. An audit includes examination, on a test basis, of evidence relevant to the amounts and disclosures in the accounts. It also includes an assessment of the significant estimates and judgements made by the Members of Council in the preparation of the accounts, and of whether the accounting polices are appropriate to the Association's circumstances, consistently applied and adequately disclosed.

We planned and performed our audit so as to obtain all the information and explanations that we considered necessary in order to provide us with sufficient evidence to give reasonable assurance that the accounts are free from material misstatement, whether caused by fraud or other irregularity or error. In forming our opinion we also evaluated the overall adequacy of the presentation of information in the accounts.

Opinion

In our opinion the accounts give a true and fair view of the state of the Association's affairs as at 31 March 2000 and of its surplus for the year then ended and have been properly prepared in accordance with the Companies Act 1985.

SCOTT-MONCRIEFF

Chartered Accountants
Registered Auditors

25 Bothwell Street
Glasgow G2 6NL

1 October 2000

Income & Expenditure Account

Year ended 31 March 2000

	Note	2000 £	1999 £
INCOME			
Natural Environment Research Council Grant-in-Aid		263,000	263,000
Other grants and income for research projects	4	864,011	857,470
UHIp external income		106,422	74,353
UHIp bequest from Yonge Fellowship		37,000	20,000
Membership subscriptions and donations		7,379	7,676
Other income		41,685	5,984
Specific funds:			
Income received	11	4,585	4,426
Transfer to specific reserves		(4,585)	(4,426)
		1,319,497	1,228,483
EXPENDITURE			
Research projects	5	990,474	980,812
UHIp		145,292	94,484
Administration salaries	6	44,782	20,203
Travel, subsistence and interview expenses		11,133	11,250
Council expenses		2,727	3,649
Postages, telephone and stationery		6,465	6,292
Printing and library		13,910	8,629
Audit fee		3,675	3,500
Other professional fees		11,570	1,058
Bursaries and small grants		2,650	5,821
Insurance		7,289	10,256
Administration, services & equipment		4,755	18,861
Marketing, publicity and newsletters		15,117	6,147
Meetings		1,909	4,650
Sundries and subscriptions		1,082	11,581
UHIp administration		-	12,594
Depreciation of fittings and equipment		45,848	56,330
Exchange differences		3,110	(328)
		1,311,788	1,255,689
Surplus (deficit) before interest		7,709	(27,206)
Interest receivable		244	1,969
Surplus (deficit) for the year	10	7,953	(25,237)

All disclosures relate only to continuing operations.
There are no gains or losses other than the surplus for the year.
The notes on pages 63 to 65 form part of these accounts.

Statement of Accounts

BALANCE SHEET

31 March 2000

	Note	2000	1999
		£	£
FIXED ASSETS			
Tangible assets	7	194,365	214,578
Investments	8	40,963	46,708
		235,328	261,286
CURRENT ASSETS			
Cash at bank and in hand		75,259	410,721
ERDF account		506	-
Yonge deposit account		2,063	11,295
Debtors	9	266,694	144,344
		344,522	566,360
CURRENT LIABILITIES			
Tax and social security		5,590	18,373
Amount due to Dunstaffnage Marine Laboratory		140,973	-
Deferred income		161,621	469,891
Sundry creditors & accruals		58,516	139,708
VAT liability		20,500	-
		387,200	627,972
NET CURRENT (LIABILITIES) ASSETS		(42,678)	(61,612)
TOTAL ASSETS LESS CURRENT LIABILITIES		192,650	199,674
CAPITAL AND RESERVES			
Reserves	10	148,648	140,695
Specific funds:			
Sheina Marshall Bequest	11	40,963	46,708
Yonge Fellowship	11	3,039	12,271
		192,650	199,674

Approved on behalf of the Council on 1 October 2000

P R BOYLE

Members of Council

M M CRAWFORD

The notes on pages 63 to 65 form part of these accounts.Year ended 31 March 2000

NOTES ON THE ACCOUNTS
Year ended 31 March 2000

1. Status

The Association is a company limited by guarantee. The liability of the Members who constitute the Association is limited to £1 per member. The affairs of the Association are managed by an elected Council of Members who constitute directors of the company for Companies Act purposes. The Association is a registered charity, Scottish Charity Number SC009206, and is not liable to income tax or corporation tax on its income under the Income and Corporation Taxes Act 1988.

2. Accounting policies

(a) Accounting convention

The accounts have been prepared under the historical cost convention and in accordance with applicable UK Accounting Standards.

(b) Fixed assets

Assets provided by or purchased from specific grants from the Natural Environment Research Council and other bodies are included in cost of fixed assets. The amount of capital grants used for the purchase of these assets is deducted from the value of the assets.

(c) Depreciation

Capital grants received to purchase vessels are equal to the cost of the vessels and therefore no depreciation on vessels is required.

The book value of the property after deduction of capital grants is considered to be equivalent to its residual value and therefore no provision for depreciation has been made.

Depreciation on fittings and equipment has been provided so as to write off the cost in equal annual instalments over their estimated useful lives of 5-8 years.

(d) Pensions

The cost of providing retirement pensions and related benefits is charged to income and expenditure over the periods benefiting from the expenditure.

3. Activities of the Association

Most of the activities of the Association are operated in conjunction with the Natural Environment Research Council. The fixed assets of the Association are leased to the Natural Environment Research Council.

4. Other grants and income for research projects

	2000	1999
	£	£
Deep-Sea Benthos	137,871	153,651
Invertebrate Surface Biology	270,860	273,092
Deep-Sea Fish	180,299	80,350
Coastal Impact	63,323	123,572
Zooplankton	47,060	13,671
Physiological Ecology of Plankton	43,644	27,048
SOAEFD	56,221	46,193
Geochemistry	64,733	139,893
	864,011	857,470

Statement of Accounts

NOTES ON THE ACCOUNTS (cont.)

5. Expenditure on research projects

	2000	1999
	£	£
Pelagic Organisms	77,510	80,930
Deep-Sea Benthos	170,026	213,514
Invertebrate Surface Biology	319,670	240,691
Deep-Sea Fish	206,257	172,553
Coastal Impact	56,329	104,581
Zooplankton	46,210	15,102
Physiological Ecology of Plankton	599	20,299
SOAEFD	48,898	17,757
Geochemistry	64,975	115,385
	990,474	980,812

6. Members of Council and other employees

The Association had 34 employees (1999: 30).

Staff costs comprise:

Wages and salaries	651,680	561,474
Social security costs	50,379	45,327
Other pension costs	75,143	58,308
	777,202	665,109

The Members of Council received no remuneration during the year (1999: nil)

7. Tangible fixed assets

	Property	Vessels	Fittings & Equipment	Total
	£	£	£	£
Cost	547,581	416,678	1,922,384	2,886,643
Additions	20,494	-	46,801	67,295
	568,075	416,678	1,969,185	2,953,938
Capital grants	(538,528)	(416,678)	(1,663,893)	(2,619,099)
At 31 March 2000	29,547	-	305,292	334,839
Aggregate depreciation				
At 1 April 1999	-	-	94,626	94,626
Charge for year	-	-	45,848	45,848
At 31 March 2000	-	-	140,474	140,474
Net book amount				
At 31 May 2000	29,547	-	164,818	194,365
At 31 March 1999	27,553	-	187,025	214,578

Year ended 31 March 2000

	2000 £	1999 £
8. Investments		
Sheina Marshall Bequest		
Flat at cost	25,673	25,673
Bank balances	13,125	13,133
Debtor	2,165	7,902
	40,963	46,708
9. Debtors		
Grants due	170,763	48,201
Amount due from Dunstaffnage Marine Laboratory	-	3,088
Other debtors	95,931	93,055
	266,694	144,344

10. Reserves

	Vessel replacement reserve £	General Reserve £	Total £
At 1 April 1999	15,000	125,695	140,695
Transfer for year	-	7,953	7,953
At 31 March 2000	15,000	133,648	148,648

11. Specific funds

	Sheina Marshall Bequest £	Yonge Fellowship £	Total £
At 1 April 1999	46,708	12,271	58,979
Bank interest received	51	768	819
Rental income	3,766	-	3,766
Property expenses	(9,562)	-	(9,562)
Total net (expenditure) income	(5,745)	768	(4,977)
Bequest in year	-	(10,000)	(10,000)
At 31 March 2000	40,963	3,039	44,002

The Sheina Marshall Bequest is an amount left by the late Dr Sheina Marshall OBE, DSC to the Association. The sum bequested was used by the Association to purchase a dwelling property in Oban which is used to accommodate visiting researchers.

The Yonge Fellowship is to commemorate the late Professor Sir Maurice Yonge. Awards will be made from the fund to suitable marine science projects. The bequest in the year is to the Scottish Association for Marine Science to support UHIp lecturers.

12. Pension Commitments

The Association participates in the Universities Superannuation Scheme, a defined benefit scheme which is externally funded and contracted out of the State Earnings-Related Pension Scheme. The assets of the scheme are held in a separate trustee-administered fund.

The latest actuarial valuation of the scheme was at 31 March 1999. The assumptions which have the most significant effect on the result of the valuation are those relating to the rate of return on investments (ie the valuation rate of interest) and the rates of increase in salary and pensions. In relation to the past service liabilities the financial assumptions were derived from market yields prevailing at the valuation date. It was assumed that the valuation rate of interest would be 4.5% per annum, salary increases would be 3.6% per annum and pensions would increase by 2.6% per annum. In relation to the future service liabilities it was assumed that the valuation rate of interest would be 5.5% per annum, including an additional investment return assumption of 1% per annum, salary increases would be 3.5% per annum and pensions would increase by 2.5% per annum. The valuation was carried out using the projected unit method.

At the valuation date, the market value of the assets of the scheme was £18,870 million (including an estimated £55 million in respect of outstanding bulk transfer payments due) and the value of the past service liabilities was £17,427 million. The assets therefore were sufficient to cover 108% of the benefits which had accrued to members after allowing for expected future increases in earnings.

The total pension cost for the Association was £75,143 (1999: £58,306). The contribution rate payable by the institution was 14% of pensionable salaries. The auditors and actuary to the Universities Superannuation Scheme have confirmed that it is appropriate to take the pension costs in the Association's accounts to be equal to the actual contributions paid during the year. In particular, the contribution rate recommended following the 1999 valuation has regard to the surplus disclosed, the benefit improvements introduced subsequent to the valuation and the need to spread surplus in a prudent manner over the future working lifetime of current scheme members.

Appendix 1

Staff at 31 March 2000

Director SAMS and DML
Unified Grade 5
Professor GB Shimmield

SAMS Staff
Secretary
Professor GB Shimmield

Unified Grade 6
Professor JD Gage

Unified Grade 7
Dr JDM Gordon

Higher Scientific Officers
Mr R Harvey (Part time)
Dr DJ Hughes
Dr JM Roberts
Dr TM Shimmield

Scientific Officers
Mr P Lamont (Part time)
Miss T Sawyer
Ms SC Swan
Miss G Thomas
Miss D Woodroffe

Assistant Scientific Officers
Miss H Lyall
Miss P McGarr

SAMS Research Fellows
Dr R Leakey
Dr JD McKenzie

NERC Research Fellows
Dr A Hatton
Dr G Tarling

UHIp Lecturers
Dr K Davidson
Dr JA Howe
Dr ME Inall
Dr AEJ Miller

Post Doctoral Research Fellows
Dr C Bavington
Dr M Grundy
Dr M Hart
Dr MS Kelly
Dr C Moss
Dr KJ Willis

Research Associates
Mr P Pantazis

Activities Manager
Mrs H Anderson (Part time)

UHIp Co-ordinator
Mrs E Munro

Data Warehouse Manager
Ms K Sinclair

EU Project Co-Ordinator
Miss L Parkinson

SAMS Honorary Research Fellows
Dr M Barnes
Professor JHS Blaxter
Dr JCA Craik
Sir Eric Denton
Dr GP Glasby
Professor JBL Matthews
Dr J Mauchline
Dr TH Pearson

DML Staff
Unified Grade 7
Dr RS Batty
Dr KD Black
Dr MT Burrows
Dr RN Gibson
Dr KJ Jones
Mr DT Meldrum
Dr J Overnell
Dr MDJ Sayer

Senior Scientific Officers
Dr C Bolch
Mr C Griffiths
Mr SM Harvey
Mr JM Watson

Higher Scientific Officers
Dr NA Auchterlonie
Dr KS Black
Mr TD Brand
Mr E Breuer
Dr C Cromey
Mr IA Ezzi
Mr R Harvey (Part time)
Dr EH John
Dr LA Nickell
Dr TD Nickell
Mr OC Peppe
Mrs LA Robb
Mr TA Wilding
Dr M Williams

Scientific Officers
Mrs CN Campbell (Part time)
Ms JM Foster
Dr S Gibson
Dr S Magill
Dr DJ Mercer
Dr P Pereira
Mr P Provost

Assistant Scientific Officers
Mr R Connop
Miss P Proudlock
Mr I Stewart

Post Doctoral Research Fellows
Dr N Navarro

Institute Secretary
Mrs EB Walton

Personnel
Ms CM Bonomy
Mrs L Thomson (Part time)

Librarian
Miss EJ Walton

Accounts
Mrs A Black
Miss F Burnip
Miss E Dudman
Mrs L Lamb
Ms E Sinclair

Director's Secretariat
Miss J McLoughlin
Mrs L Birrell (Part time)

General Office
Mrs J MacAskill
Mrs L Thomson (Part time)

Computing Support
Mr GC Ryan
Mrs K Smalley

Technical Support
Mr BH Clark

Aquarium Manager
Mr A Keay

Building Maintenance
Mr DN MacKinnon
Mr AC Black

Storeman
Mr G Webster

Diving and Small Boats
Dr S Thurston
Mr R Wood

Ships: RV *Calanus* and RV *Seol Mara*
Mr SF Douglas (Motorman)
Mr F Lovie (Crew)
Mr J MacFarlane (Engineer)
Mr D McAlpine (Bosun)
Mr GB McMillan (Skipper)
Mr GJR Murphy (Mate)

Sandwich students carrying out their industrial placements at the Laboratory
E Alorend, University of Caen
G Bally, Blaise Pascal, France
J Cocker, University of Bradford
S Dixon, University of Bradford
P Enot, University of Rouen
J Fairbrass, University of Bristol
S Faulkner, University of Hertfordshire
S Marin, University of Cadiz
N Monerris, University of Cadiz
P Owen, University of Bradford
R Saunders, University of Bradford
S Schwalbe, University of Freisling
J Youlden, University of Bradford

Appendix 2

Refereed Publications and Peer-reviewed articles in ISI Database

ANDREN, E, SHIMMIELD, G B and BRAND, T D, 1999. Environmental changes of the last three centuries indicated by siliceous microfossil records from the southwestern Baltic Sea. *Holocene* 9, 25-38.

ANSELL, A D, COMELY, C A and ROBB, L, 1999. Distribution, movements and diet of macrocrustaceans on a Scottish sandy beach with particular reference to predation on juvenile fishes. *Marine Ecology Progress Series* 176, 115-130.

ANSELL, A D, HARVEY, R and GUNTHER, C P, 1999. Recovery from siphon damage in *Donax vittatus* (Da Costa) (Bivalvia: Donacidae). *Journal of Molluscan Studies* 65, 223-232.

ARMSTRONG, E, McKENZIE, J D and GOLDSWORTHY, G, 1999. Aquaculture of sponges on scallops for natural products research and antifouling. *Journal of Biotechnology* 70, 163-174.

BAKER, J M, REEVES, C E, NIGHTINGALE, P D, PENKETT, S A, GIBB, S W and HATTON, A D, 1999. Biological production of methyl bromide in the coastal waters of the North Sea and the open ocean of the northeast Atlantic. *Marine Chemistry* 64, 267-285.

BARNES, M, 1999. The mortality of intertidal cirripedes. *Oceanography and Marine Biology: an Annual Review* 37, 153-244.

BERGSTAD, O A, BJELLAND, O and GORDON J D M, 1999. Fish communities on the slope of the eastern Norwegian Sea. *Sarsia* 84, 67-78.

BREUER, E, SANUDO-WILHELMY, S A and ALLER, R C, 1999. Trace metals and dissolved organic carbon in an estuary with restricted river flow and a brown tide bloom. *Estuaries* 22 (3A), 603-615.

BURROWS, M, THORPE, S A and MELDRUM, D T, 1999. Dispersion over the Hebrides and Shetland shelves and slopes. *Continental Shelf Research* 19, 49-55.

BURROWS, M T, HAWKINS, S J and SOUTHWARD, A J, 1999. Larval development of the intertidal barnacles *Chthamalus stellatus and Chthamalus montagui. Journal of the Marine Biological Association of the United Kingdom* 79, 93-101.

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Appendix 3

Postgraduate Research Projects

Degrees awarded during the reporting year

E J Cook, Ph.D, Napier University. *Psammechinus miliaris* (Gmelin) (Echinodermata: Echinoidea) Factors affecting its somatic growth and gonadal growth and development and its suitability as a species for sea urchin cultivation. (M S Kelly, J D McKenzie, PA Read and T Fernandez)

H Smith, Ph.D, The University of Southampton. New approaches to modelling sympatric speciation in animals. (G Turner, L Noble and M T Burrows)

J Smith, Ph.D, The University of Edinburgh. The marine geochemistry of barium and radium. (G B Shimmield)

Ongoing research

S Craig, Ph.D. The University of Aberdeen. The developmental plasticity of Loliginid squid; developmental biology and biochemical composition of the eggs of the squid *Loligo forbesi* Steenstrup, (P Boyle, K D Black and J Overnell)

P Crozier, Ph.D, The University of the Highlands and Islands project. The impact of deep-water fisheries on elasmobranch populations in the north east Atlantic. (J D M Gordon and P Vass)

L Darrock, Ph.D, The University of East Anglia. Dimethylsulphoxide: origin, fate and cycling. (P S Liss, G Malin and A D Hatton)

R Dean, Ph.D, The University of the Highlands and Islands project. Biogeochemical cycling in fish farm sediments. (T M Shimmield, K D Black and P Gillibrand)

V Edwards, Ph.D, Napier University. Yield of marine phytoplankton chlorophyll from dissolved organic nitrogen under eutrophic conditions. (P Tett, K J Jones, S Bury and R Park)

S A Fleming, Ph.D, The University of Glasgow. Mercury accumulation in deep-sea fish. (R W Furness, I M Davies and J D M Gordon)

N Frost, Ph.D, The University of Southampton. Spatial heterogeneity and community stability on rocky shores. (S J Hawkins, M T Burrows and M P Johnson)

T Jarvis, Ph.D, The University of the Highlands and Islands project. The vertical export of material caused by zooplankton vertical migration. (G A Tarling, J B L Matthews, G C Hays)

J B Kristoffersen, Ph.D, The University of Bergen. Life history of mesopelagic fish in Norwegian waters. (A G V Salvanes and J D M Gordon)

S Mormede, Ph.D, The University of Glasgow. Contaminants in deep-water fish stocks. (I M Davies, J D M Gordon and R W Furness)

D Nairn, Ph.D, The University of the Highlands and Islands project. Sense organ development in cultured halibut larvae and implications for first feeding. (R S Batty and C Cutts)

B E Narayanaswamy, Ph.D, The University of Southampton. The ecology of macrobenthos in the Faeroe-Shetland Channel. (J D Gage, J P Hartley and P A Tyler)

O Obajimi, Ph.D, The University of the Highlands and Islands project. Antioxidant and anti-phospholipase activity by marine carotenoids. (I Glen and J D McKenzie)

G Spyres, Ph.D, The University of Plymouth. Dissolved organic matter dynamics over the Iberian Shelf. (M Nimmo, A E J Miller and P Worsfold)

O Costa, Ph.D, The University of Plymouth. Brazilian coral reef biogeochemistry. (M Attrill, M Nimmo and A E J Miller)

V Jones, Ph.D, The University of Liverpool. Organic nitrogen biogeochemistry. (G V Wolff, A E J Miller)

M del Mar Otero-Villanueva, Ph.D, The University of the Highlands and Islands project. Energy partitioning: growth and reproductive strategies in the sea urchin *Psammechinus miliaris*. (MS Kelly and G Burnell)

T A Wilding, Ph.D, Heriot-Watt University. Environmental and ecological impacts of artificial reefs. (M D J Sayer and C Moore)

Appendix 4

Research grants and contract income received

DML

Project Leader	Title	Funding body	Duration	Award
R Batty, R Leakey	Rearing protocols for Atlantic halibut larvae during transition from endogenous to exogenous nutrition	MAFF LINK Aquaculture	01/00 – 12/02	£146k
KD Black	The ecological effects of sea lice treatment agent	Veterinary Medicine Directory of MAFF, DETR, The Scottish Executive, SNH, SNIFFER and Scottish Quality Salmon	09/99 – 08/02	£221k
KD Black	Serpulid (*Serpula vermicularis*: Polychaeta) reef survey in Rhugh Garbh, Loch Creran	Foster Yeoman Ltd	05/99	£8k
KD Black, J Overnell	Developmental plasticity of Loliginid Squid. (DEMA)	NERC	10/97 – 10/00	£29k
KD Black, KJ Jones	Planktonic ecosystem impacts of aquaculture	EU Marie Curie Fellowship	02/98 – 02/00	Ecu91k
CHJ Cromey	Modelling Lagavullin Distillery outfall	Montgomery Watson	02/99 – 04/99	£5k
J Overnell, KD Black	Measurement of dissolved and particulate manganese and oxygen concentrations using Autosub in two Scottish sea lochs. (Autosub Science Missions)	NERC	03/99 – 03/01	£160k
P Provost	Environmental monitoring and modelling	Ardvar Salmon Ltd	07/99 –12/99	£8k
MDJ Sayer	Lumpsucker culture: species diversification using existing infrastructure	MAFF/NERC LINK Aquaculture	12/96 – 05/99	£152k
MDJ Sayer	Feasibility of artificial reef deployments on the west coast of Scotland	EU PESCA Foster Yeoman Ltd Argyll & Islands Enterprise Lochaber Enterprise	11/97 – 05/00	£154k
MDJ Sayer	Juvenile gadoids in the rocky subtidal: factors affecting abundance and distribution	MAFF	04/95 – 05/00	£352k
MDJ Sayer	Fish Farming Diversification: Lumpsucker culture	EU PESCA Highland Council Highland & Islands Enterprise	05/99 – 03/00	£30k
MDJ Sayer	Inshore benthic sediment structure determination and mapping of the western Gulf of Mexico	University of Southampton	12/99 – 12/00	£280k
MDJ Sayer	Recompression treatment in Scotland: technical audit and website construction	NHS Scotland	12/99 – 12/03	£40k
MDJ Sayer	Commercial scale assessment of the efficacy of the use of wrasse as control agents for sealice infestation of farmed salmon	Western Isles Enterprise	02/00 – 12/00	£2.5k

Appendix 4

SAMS

Project Leader	Title	Funding body	Duration	Award
K Davidson	CN budgets and trophic selections within marine microbial food webs. (PRIME)	NERC	02/98 – 05/01	£77k
K Davidson	Phytoplankton growth modelling under multi-nutrient limitation	NERC	07/00 – 06/01	£17k
K Davidson	Diatom growth dynamics using Trondheim Marine Systems large scale facility	EC	04/99 – 06/99	In kind
K Davidson	The influence of Micro-zooplankton on marine productivity. (Marine Productivity)	NERC	01/00 – 06/01	£54k
JD Gage	Sensitivities of cold-water corals and other large benthic fauna in relation to oil/gas activities west of Shetland. (MIME)	NERC	04/97 – 09/99	£150k
JD Gage	Sensitivities of cold-water corals and other large benthic fauna in relation to oil/gas activities west of Shetland. (MIME)	MTS	04/97 – 09/99	£16k
JD Gage	Benthic community activity and biomass at the deep-ocean bed. (BENBO)	NERC	01/98 – 12/00	£103k
JD Gage	Benthic ecology of the Faeroe- Shetland Channel PhD studentship	Atlantic Frontier Environmental Network, (AFEN)	01/98 – 01/01	£30k
JD Gage	Benthic biological studies in the Atlantic Frontier	Geotek Ltd. on behalf of AFEN	06/98 – 04/00	£36k
JDM Gordon	Seasonal changes in biological and ecological traits of demersal and deep-water fish species in the Azores	EC DGXIV	03/98 – 02/00	Ecu9k
JDM Gordon	Development of Elasmobranch Assessments (DELASS)	EC DGXIV	01/00 – 12/02	Ecu10k
AD Hatton	Biogenic trace gases; NERC Fellowship	NERC	09/97 – 09/00	£100k
AD Hatton	Seasonal cycles; small grant	NERC	09/98 – 10/99	£25k
JA Howe	Bottom-current pathways in the northern and central Rockall Trough	Rockall Oil Consortium	04/99 – 03/00	£5k
JA Howe	Drill cuttings literature review (geology)	UKOOA	10/99 – 11/99	£5k
MS Kelly	Commercially viable sea urchin cultivation	EC FAIR (CRAFT)	11/98 – 11/00	Ecu 600k
MS Kelly	Occurrence and distribution of the ASP toxin in king scallop population on the west coast of Scotland	HIE, Highland Council, PESCA and the Scallop Association	12/99 – 05/00	£34k
MS Kelly	Accelerating growth rates in the king scallop Pecten maximus	Argyll and Islands Enterprise and Single Shell Systems	09/99 – 08/00	£40k
R Leakey	Assessment and management of coastal pollution	British Council Higher Education Link programme	04/99 – 03/02	£30k

Appendix 4

Project Leader	Title	Funding body	Duration	Award
JD McKenzie	Novel methods for supplying organisms of interest in natural product drug research	EC CRAFT – Full collaborative project	01/99 – 12/00	Ecu289k
JD McKenzie	Plate based microbial assay systems for marine ecotoxicology	EC CRAFT – Full collaborative project	01/99 – 12/00	Ecu342k
AEJ Miller	Bloom dynamics of dissolved organic matter: linking the carbon and sulphur cycle	Nuffield Foundation	02/00 – 02/02	£4k
JM Roberts	Aquarium studies on the cold water coral *Lophelia pertusa*	AFEN	07/99 – 09/99	£7k
JM Roberts	Occurrence of *Lophelia* on Beryl Alpha platform	Mobil North Sea Ltd	10/99	£5k
JM Roberts	Review of video records showing coral around the Brent Alpha platform	United Kingdom Offshore Operators Association, (UKOOA)	01/00	£1k
GB Shimmield	Sediment transport and fluxes from a river mouth to a deep basin environment: Baltic Sea System Study (BASYS)	EC MAST-III	09/96 – 09/99	Ecu108k
GB Shimmield	Atlantic database for exchange processes at the deep sea floor (ADEPD)	EC	11/97 – 11/99	Ecu5k
GB Shimmield	Science and management of marine Special Areas of Conservation (with SNH, EN, WCC and DANI)	EC LIFE	04/97 – 03/00	£127k
GB Shimmield	Marine Science Degree support	UHIp	09/98 – 09/00	£100k in joint funding
GB Shimmield	Sedimentary evolution of the north Norfolk barrier island coastline in the context of Holocene sea level change: Land Ocean Interaction Study (LOEPS and RACS)	NERC	4/94 – 9/97	£50k
GB Shimmield	A geochemical and radiochemical appraisal of offshore drill cuttings as a means of predicting possible environmental impact after site abandonment (MIME)	NERC and Oil Industry	6/97 – 5/00	£127k
GB Shimmield	Organic and Inorganic Transformations at the Benthic Boundary Layer (BENBO)	NERC	8/97 – 7/00	£193k
GB Shimmield	Deep Ocean Benthic Boundary Layer Programme Science Co-ordinator and Management (BENBO)	NERC	8/97 – 7/00	£133k
GB Shimmield	Decadal Climate Variability and the El Nino Southern Oscillation: High resolution records of Ocean Atmosphere Interactions from corals in the Central South Pacific	NERC	6/99 – 5/02	£197k
GB Shimmield	Ph.D. Student support	UHIp	02/99 onward	£1.5k per student place
GA Tarling	NERC Fellowship: Ecology of Zooplankton in the Clyde Sea	NERC	09/98 – 08/01	£97k
G A Tarling	The impact of sea-lice treatments on zooplankton communities in the vicinity of salmon farms	MAFF/Veterinary Medical Directorate	07/99 - 08/02	£95k